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Indira Gandhi National
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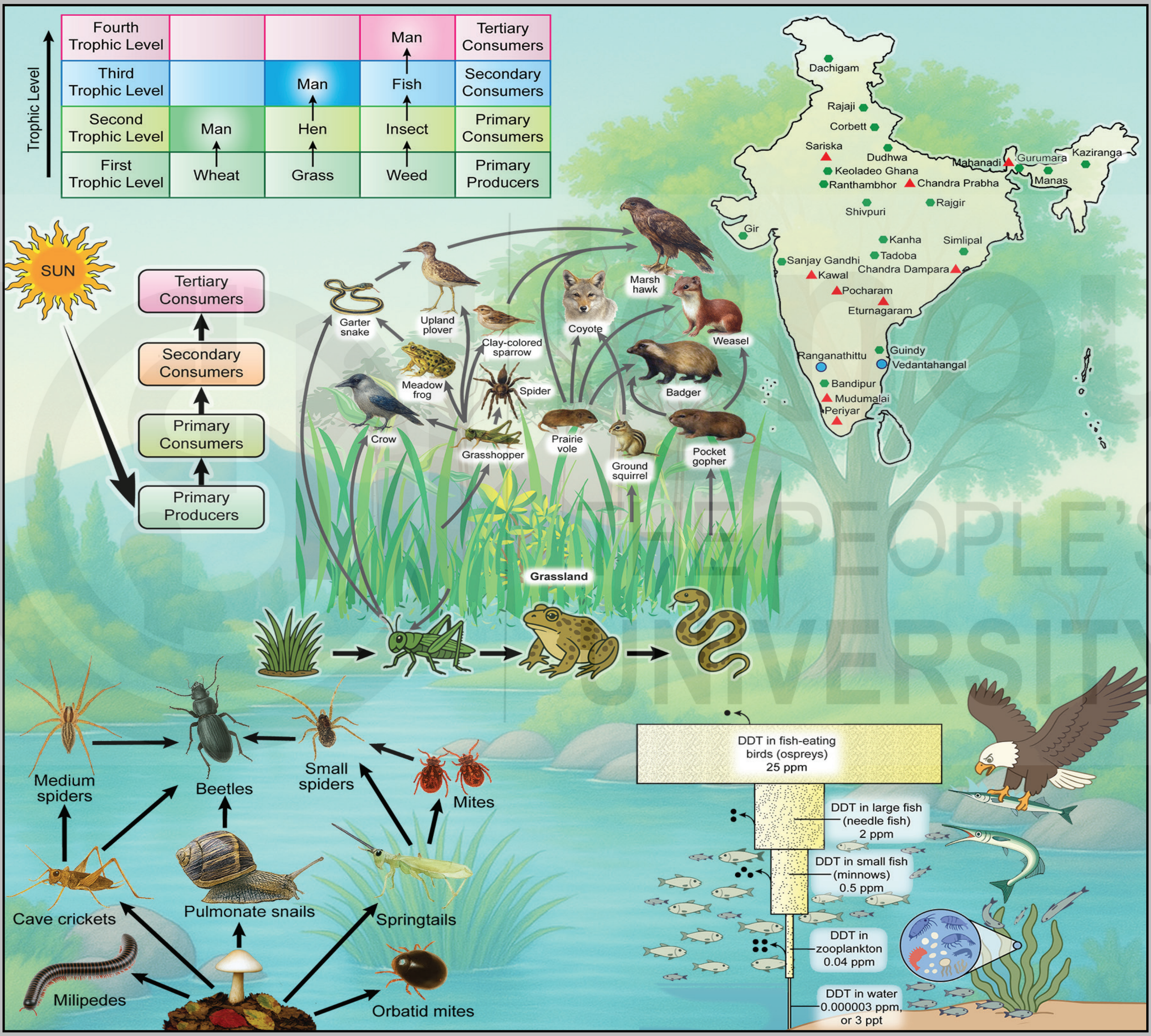
School of Sciences

MZO-007
PRINCIPLES OF ECOLOGY


Trophic Level
Fourth Trophic Level
Man
Tertiary Consumers
Third Trophic Level
Man
Fish
Secondary Consumers
Second Trophic Level
Man
Hen
Insect
Primary Consumers
First Trophic Level
Wheat
Grass
Weed
Primary Producers
SUN
Tertiary Consumers
Secondary Consumers
Primary Consumers
Primary Producers
Garter snake
Upland plover
Clay-colored sparrow
Meadow frog
Spider
Crow
Grasshopper
Prairie vole
Coyote
Marsh hawk
Weasel
Badger
Ground squirrel
Pocket gopher
Grassland
Dachigam
Rajaji
Corbett
Sariska
Dudhwa
Keoladeo Ghana
Ranthambhor
Chandra Prabha
Mahanadi
Gurumara
Kaziranga
Manas
Rajgir
Shivpuri
Gir
Kanha
Simlipal
Tadoba
Sanjay Gandhi
Chandra Dampara
Kawal
Pocharam
Eturnagaram
Ranganathittu
Guindy
Vedantahangal
Bandipur
Mudumalai
Periyar
Medium spiders
Beetles
Small spiders
Mites
Cave crickets
Pulmonate snails
Springtails
Milipedes
Orbatid mites
DDT in fish-eating birds (ospreys) 25 ppm
DDT in large fish (needle fish) 2 ppm
DDT in small fish (minnows) 0.5 ppm
DDT in zooplankton 0.04 ppm
DDT in water 0.000003 ppm, or 3 ppt

VOLUME 2

BIODIVERSITY CONSERVATION AND ENVIRONMENTAL CHALLENGES
(Blocks 3 and 4)

Indira Gandhi
National Open University
School of Sciences

MZO-007
PRINCIPLES OF ECOLOGY

VOL
2

BIODIVERSITY CONSERVATION AND ENVIRONMENTAL CHALLENGES

BLOCK 3
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Major Environmental Issues 157

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VOLUME 2 : BIODIVERSITY CONSERVATION AND ENVIRONMENTAL CHALENGES

Ecology is the scientific discipline that investigates how organisms interact with each other and with their environment, encompassing processes such as energy flow, nutrient cycling, population dynamics, biodiversity, and the impacts of environmental change. The "**Principles of Ecology**" course provides an in-depth and advanced study of ecological science, aiming to equip learners with a comprehensive understanding of the complex relationships that shape ecosystems. It combines foundational ecological theory with applied concepts, enabling learners to critically examine ecosystem structure, function, and responses to natural and anthropogenic pressures across multiple levels of biological organisation.

The "Principles of Ecology" is the four-credit course that covers fundamental concepts of ecosystem structure and function, population ecology, biodiversity conservation, and major environmental issues. The course content is structured into two volumes, each comprising thematic blocks. **Volume 1 (Ecosystem Dynamics and Population Ecology)** consists of Block 1 (Ecosystem and its Functioning) and Block 2 (Population Ecology). The present **Volume 2 (Biodiversity and Environmental Challenges)** of the course also consists of two blocks: Block 3 (Biodiversity and its Conservation) and Block 4 (Major Environmental Issues). This volume of the course delves into the fascinating diversity of life on Earth and the critical environmental challenges facing ecosystems today. It begins with an exploration of biodiversity at genetic, species, ecosystem, and landscape levels, emphasising its ecological roles, economic value, and significance for sustainable development. Learners will gain insights into conservation strategies, both traditional and modern, and examine key international agreements and molecular tools essential for biodiversity research and protection. The volume also addresses major global issues such as climate change, pollution, toxic contaminants, and sustainable waste management, focusing on how these stressors disrupt ecological balance and human well-being. Through this study, students will develop scientific and analytical skills to assess biodiversity, evaluate environmental impacts, and contribute effectively to conservation and environmental management in a rapidly changing world.

Biodiversity encompasses genetic, species, and ecosystem diversity, forming the foundation of ecosystem resilience and functional integrity. **Block 3 (Biodiversity and its Conservation)** delves into methods for quantifying biodiversity, its ecological and economic significance, the drivers and impacts of biodiversity loss, and global conservation frameworks, including *in situ* and *ex situ* strategies. Additionally, it introduces tools such as the molecular clock, Hardy-Weinberg equilibrium, and analyses of mating systems, equipping students with advanced approaches for biodiversity assessment and conservation biology. These topics are discussed in detail in five Units (Units 9 to 13).

Block 4 (Major Environmental Issues), which consists of four Units (Units 14 to 17), focuses on understanding and managing key environmental problems affecting ecosystems and human well-being. It covers climate change, explaining processes like ozone depletion, global warming, and changing weather patterns, and discusses scientific methods to cope with these challenges. The Block discusses the environmental pollutants, detailing how contaminants enter organisms, accumulate in tissues, and cause toxicity, and how detoxification works at molecular and physiological levels. It also explores pesticides and their types, effects on living systems, risks of accumulation in ecosystems, and safe management practices, supported by real-life examples. Lastly, this Block also discusses the waste generation, classification, and modern methods for treating and disposing of waste sustainably, emphasising how these practices impact soil, water, and air quality.

Objectives

After studying this volume, you should be able to:

- explain key environmental stressors associated with climate change, including ozone depletion, global warming, and shifting climatic patterns, and describe management strategies to mitigate their impacts.
- discuss coping strategies for climatic variations, highlighting scientific and technological approaches for adaptation and resilience in ecosystems.
- identify major environmental contaminants and explain how these pollutants are taken up by organisms and accumulate in biological systems, leading to bioaccumulation and biomagnification.
- describe mechanisms of toxicity, including how contaminants exert harmful effects at molecular and physiological levels, and outline processes for detoxification and elimination from living organisms.
- understand the ecological roles and impacts of pesticides, classifying them by type and use in agriculture, industry, and other sectors, and explain their interactions with biological systems.
- analyse long-term ecological risks associated with pesticide accumulation, and evaluate safe disposal, waste management techniques, and regulatory measures for pesticide pollution.
- assess the environmental consequences of pesticide use, including impacts on soil microorganisms, plants, animals, and ecosystem functioning, supported by relevant case studies and mitigation strategies.
- comprehend waste generation and classification, distinguishing among industrial, agricultural, municipal, and hazardous wastes, and explain sustainable practices for managing waste to protect ecosystems.
- describe treatment methods, *viz.* biological, chemical, and physical, for effective waste management, including microbial digestion, bioremediation, and the molecular processes involved in biological treatments.
- evaluate environmental impacts of waste management techniques on soil, water, and air quality, and understand innovative strategies for the safe disposal of hazardous wastes to promote sustainability.

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PRINCIPLES OF ECOLOGY

Block

3

ECOSYSTEM AND ITS FUNCTIONING

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UNIT 12
Conservation and Management of Biodiversity 88

UNIT 13
Molecular Ecology and Its Applications 128

COURSE NAME: PRINCIPLES OF ECOLOGY **COURSE CODE: MZO-007**

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BLOCK 3: ECOSYSTEM AND ITS FUNCTIONING

Biodiversity forms the foundation of ecological science, encompassing the variety of life at all levels of biological organisation. **Block 3 (Biodiversity and its conservation)** introduces the concept of biodiversity and its three key levels: genetic, species, and ecosystem diversity, along with standard methods for their assessment. It highlights the importance of biodiversity in supporting ecological balance, providing resources like food, medicine, and clean air and water, and its role in climate regulation and ecosystem resilience. Learners will study the causes and consequences of biodiversity loss, understand how to evaluate its value, and explore the need for its protection. The Block also covers global and national conservation efforts, including legal frameworks and both in situ and ex situ conservation methods. Finally, students will be introduced to molecular ecological tools such as the molecular clock, Hardy-Weinberg equilibrium, and mating systems, which support modern biodiversity research and conservation planning. Block 3 contains five Units (Units 9 to 13) to discuss these concepts of biodiversity and its conservation in detail.

In **Unit 9 (Concept of biodiversity-I)**, you will learn what biodiversity is and explore its different levels, including genetic, species, ecosystem, and landscape diversity. You will also study how researchers measure biodiversity to understand the richness and health of nature. These skills help in protecting species and managing ecosystems wisely. This Unit will give you a solid foundation for studying conservation and ecological research.

Unit 10 (Concept of biodiversity-II) explains how biodiversity provides essential products like food, medicines, and raw materials, and crucial services such as pollination, climate regulation, and nutrient cycling. It examines human activities that cause biodiversity loss, like habitat destruction, pollution, and climate change, and discusses their impacts on ecosystems. Lastly, it highlights the economic importance of conserving biodiversity for sustainable development.

Unit 11 (International conventions and other initiatives for biodiversity protection) explains how biodiversity is protected through international agreements and national laws. It covers global conventions like the IUCN, CBD, CITES, Ramsar, and the Global Biodiversity Framework, which set rules and goals for conserving species and habitats. It also describes India's laws, including the Wildlife Protection Act, Forest Protection Act, Environment Protection Act, and Biodiversity Act 2002, which help manage and conserve biodiversity within the country. The unit discusses how biosafety rules are used to safely handle biological resources and genetic material. By studying this unit, students will understand how legal tools and policies work together to protect biodiversity worldwide and in India.

Unit 12 (Conservation and management of biodiversity) explains the different conservation strategies for biodiversity. It explains in situ conservation, where species are protected in their natural habitats, and *ex situ* conservation, where species are preserved outside their habitats in places like zoos, seed banks, and botanical gardens. The Unit also discusses how traditional ecological knowledge helps local communities manage biodiversity sustainably. By learning these methods, learners will understand practical tools to protect species and ecosystems.

Unit 13 (Molecular ecology and its applications) explains how sustainable development relates to ecology and genetics. It covers molecular ecology and how genes help study single and multiple populations, including concepts like Hardy-Weinberg equilibrium, bottlenecks, and natural selection. Students will learn how to measure differences between populations and understand how gene flow and movement affect species. The Unit also shows how DNA tools help trace species' history and study animal behaviour, like mating systems and mate choice. This Unit builds important skills for using genetics in ecology and conservation.

Objectives

After completing this block, you should be able to:

- define biodiversity and describe its different levels, including genetic, species, ecosystem, and landscape diversity.
- explain how biodiversity is measured, using various methods and indices for genetic, species, and ecosystem diversity.
- discuss the ecological and economic importance of biodiversity, including its role in providing goods like food, medicine, and raw materials, and services such as climate regulation and nutrient cycling.
- describe the uses of biodiversity in medicine, ornamental applications, recreation, tourism, and scientific research.
- identify the main factors causing biodiversity loss globally, such as habitat destruction, overexploitation, pollution, and climate change.
- analyze the major impacts of biodiversity loss on ecosystems, human well-being, and sustainable development.
- explain how biodiversity is valued, including its ecological, economic, cultural, and scientific significance, and why protection is necessary.
- describe key national and international laws, conventions, and agreements focused on biodiversity conservation.
- explain the biodiversity conservation methods, including *in situ* and *ex situ* strategies, and discuss global initiatives for biodiversity protection.
- understand molecular ecology concepts like molecular clocks, phenotypic plasticity, Hardy-Weinberg equilibrium, and different mating systems and mate choice strategies in biodiversity studies.

UNIT 9

CONCEPT OF BIODIVERSITY-I

Structure

9.1 Introduction
  Objectives
9.2 Defining Biodiversity
9.3 Levels of Biodiversity
  Genetic Diversity
  Species Diversity
  Ecosystem Diversity
  Landscape Diversity
9.4 Measuring Biodiversity
  Measuring Species Diversity
  Measuring Genetic Diversity
  Measuring Ecosystem Diversity
9.5 Summary
9.6 Terminal Questions
9.7 Answers

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9.1 INTRODUCTION

Biological diversity is the new buzzword, the magic door to international funding and global travelling. We share the earth with million of other living beings. Just as we humans make up one species, there are perhaps five to thirty million other species comprising plants like neem and rice, animals like the elephant and peafowl, and micro-organisms too small to see with the naked eyes. India alone has 1, 25, 000 recorded species, and perhaps many more times that number which are yet undiscovered. This range of life form is called **biological diversity** or **biodiversity**.

The earth's biodiversity has taken more than 3000 million years to evolve, and today, it forms the basis for survival of the human species and other life forms on our planet. When we speak of global biodiversity we speak of the totality of genetic strains, species and ecosystems in the entire world. Similarly, we can also speak of biodiversity at a more localised level, such as in a continent, a region such as South Asia, a country or even a province.

The countries of South Asia have a high biodiversity, as it contains vast continental areas covering Bangladesh, Bhutan, India, Nepal and Pakistan, as well as islands such as Sri Lanka and the Maldives. This provides the region with a wide range of ecosystems and habitat types. The climate across the region also varies considerably, while the altitude ranges from flat coastal areas to Everest, the highest mountain in the world. The region is also important in terms of in-country endemics and is consequently important in terms of global biodiversity as well as at the national level for the countries within this region.

> "The countries of Asia have great biodiversity importance and richness, ranking with South America as the richest place on earth for variety of living forms. Of the world's 25 recognised biodiversity hot spots, seven are in Asia. These hot spots cover the Western Ghats of India, Sri Lanka, and the eastern Himalayan countries of Nepal, Bhutan and India."
>
> **Source:** MacKinnon (2002) in Biodiversity Planning in Asia, IUCN.

Our earth and the atmosphere around it contain millions of **species**, in a bewildering array of shapes, sizes and organisational structures. These species occur in a wide range of **ecosystems**, and contain billions of **genes** which make each species, and even individuals within a species, different from one another.

In the present unit you will study as to what biodiversity is, and what are the different levels of biodiversity. You will also study about measures of biodiversity as conservation strategies are based on these measures.

Objectives

After studying this unit, you should be able to:

- define biodiversity;
- explain different levels of biodiversity i.e. genetic diversity, species diversity, ecosystem diversity; and
- describe basis to measure different levels of biodiversity.

9.2 DEFINING BIODIVERSITY

Biodiversity, or **biological diversity,** is a neologism and portmanteau word, from **'bio' and 'diversity'**. It is the diversity of and in living nature. Diversity, at its heart, implies the number of different kinds of objects, such as species. However, defining biodiversity or measures of biodiversity, is not so simple.

The term biological diversity, was coined by **Thomas Lovejoy** in 1980, while the word biodiversity itself, was coined by the entomologist **E.O. Wilson** in 1986, in a report for the first American Forum on biological diversity organized by the National Research Council (NRC).

Biological diversity has no single standard definition. One definition holds that biological diversity is a *measure of the relative diversity among organisms present in different ecosystems*. "Diversity" in this definition includes diversity within species, among species, and comparative diversity among ecosystems.

Another definition, simpler and clearer, but more challenging, is the *totality of genes, species, and ecosystems of a region*. An advantage of this definition is

Neologism is a recently coined word or the act of inventing a word or phrase. Additionally it can imply the use of old words in a new sense such as giving new meanings to existing words or phrases.

A portmanteau word (sometimes called a blend or franken word) is a word that is formed by combining two or more words. The meaning of the word was coined by Lewis Carroll.

that it seems to describe most instances of its use, and one possibly unified view of the traditional three levels at which biodiversity has been identified:

- **genetic diversity** - diversity of genes within a species. There is a genetic variability among the populations and the individuals of the same species.
- **species diversity** - diversity among species.
- **ecosystem diversity** - diversity at a higher level of organization, the ecosystem (richness in the different processes to which the genes ultimately contribute). You will study about these concepts in detail in the following sections.

The lattermost definition, which conforms to the traditional five organisation layers in biology, provides additional justification for multilevel approaches.

The 1992 Earth Summit in Rio de Janeiro defined biodiversity as:

> *The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.*

Wide diversity in terrestrial ecosystems can be seen in South Asia due to the vast variety of natural landforms and climate which have given rise to habitats ranging from tropical to temperate, alpine to desert and coastal to montane. **Freshwater aquatic biodiversity abounds in South Asia in natural water bodies such as rivers, lakes, ponds, reservoirs and swamps**.

Biodiversity found on Earth today is the result of 3.5 billion years of evolution. Until the emergence of humans, the Earth supported more biodiversity than in any other period in geological history. Since the advent of humans, however, biodiversity has begun a rapid decline, with one species after another suffering extinction.

Estimates of global species diversity vary from 2 million to 100 million species, with a best estimate to somewhere near 12.5 million.

New species are regularly discovered (on an average about three new species of birds each year) and many, though discovered, are not yet classified (an estimate gives that about 40% of freshwater fishes from South America are not yet classified). **Most of the diversity is found in tropical forests**.

Box 9.1: Where does most of the world's biodiversity exist?

Biodiversity is everywhere, in deserts, oceans, freshwater bodies, tropical rainforests, temperate zone forests and your backyard. The rainforests of Central and South America, equatorial Africa, and Southeast Asia may house at least half of the world's species. A large number of plant and animal species call coral reefs – the "rainforests of the seas" – their home. Lakes, estuaries, the deep ocean floor and the soil beneath your feet are also rich in biodiversity, while extreme arctic climates and torrid deserts contain some of the most unusual living organisms.

What are genes? …

Genes are the basic units of heredity in an organism which are passed down by an organism to its offspring. They act as strorehouses of the heritable characteristics of an organism.

1. Genes are made up of a complex organic molecule called **deoxyribonucleic acid (DNA)** which comprises a linear molecule made up of four types of building blocks, or nucleotide bases. A strand of DNA has two strings of nucleotides twisted around each other, with loose attachments between nucleotide pairs.
2. Genetic diversity arises due to the variation in the sequence of nucleotide pairs of DNA strands.
3. In higher organisms, the bulk of DNA is packaged in a linear form within chromosomes located in the cell nuclei of these organisms.
4. Chromosomes occur in pairs in each cell of an organism. One of each pair is inherited from the father while the other is received from the mother. Humans have 23 pairs of chromosomes.

SAQ 1

a) Define biodiversity.

b) Who coined the terms ‘biodiversity’ and ‘biological diversity’?

9.3 LEVELS OF BIODIVERSITY

There are three levels of diversity *viz*. **genetic**, **species** and **ecosystem** diversity. In effect, these levels cannot be separated. Each is important, interacting with and influencing the others. A change at one level can cause changes at the other levels.

9.3.1 Genetic Diversity

Genetic diversity is the “fundamental currency of diversity” that is responsible for variation. This hereditary information is passed down to generations within a species (e.g., different varieties of the same species).Genetic diversity underlies the variability (differences) among individuals of a given species. For example, no two individuals even in the same family are identical, unless of course they are identical twins with the same genome (i.e. complete genetic makeup). This is true for all species, because any individual resulting from sexual reproduction, except identical twins, has a slightly different combination of genes from another individual. The differences in the genetic makeup of organisms also form the basis for variation within a population, or between populations, of that species. Thus, genetic diversity within a species will increase with the number of individuals of a given species. It is estimated that there are about 10^9 different genes distributed throughout the world’s biota (i.e. living component).

It is genetic diversity that allows a species to adapt to changing environmental conditions, such as lower rainfall or higher temperatures year round. The effective conservation of genetic diversity within a species cannot, however, be achieved by merely conserving the species. This is because the conservation of one or a few populations of a species cannot lead to conservation of genetic diversity. For example, conserving one or more populations of a species may conserve the species as a whole but may not serve to capture its entire genetic diversity. For example, losing even a single one results in the loss of genetic variation. Sometimes the lost variation of a gene may even be crucial for the future survival of the species in the face of changing environmental conditions.

Box 9.2: The problem of survival among cheetahs

Once quite widespread throughout Asia and Africa, there has been a large reduction of the cheetah’s habitat and numbers though it is still seen in widely separated areas of Africa. Recent surveys of cheetah populations have shown that there is almost no genetic variation among individuals, even among those taken from the furthest points of its range. This is due to an evolutionary “bottleneck” caused by the fact that at one point cheetah populations crashed to very low numbers and then expanded from the same stock. As a result, cheetahs in the wild, as well as in captivity, show several problems due to inbreeding which is threatening its future survival. The problems encountered are low sperm counts leading to reproductive difficulties, low survival of juveniles, morphological aberrations and high susceptibility to diseases because of low genetic diversity in the immune system. Thus, even when numbers seem relatively adequate for a given species, a low genetic diversity can increase its vulnerability to extinction.

Genetic diversity is, thus, important for the preservation of species diversity, and hence biological diversity. A knowledge of the variability of genes also allows us to understand how closely individuals or species are related to each other. **Genetic diversity between species becomes greater with increasing distance in the relationship of species.** Consequently, more distantly related species will represent a higher range of genetic diversity than closely related species. Genetic variability responsible for these different traits, interacts with local environmental conditions to determine the extent to which populations can adopt to environmental changes. Isolated population such as those on ocean, islands or in small patches of habitats cut off from the surrounding environment tend to have less genetic variation, hence more susceptible to extinction.

9.3.2 Species Diversity

Species diversity means the differences between species (both domesticated and wild). It is the most visible component of biodiversity as implied by the word ‘species’ which literally means outward or visible form. This is why we often tend to describe biological diversity in terms of the number of species in a particular area or at the global level.

Box 9.3: What is a species?

There are many interpretations of what a species really is.

The biological species concept

A biological species as defined by Ernst Mayr are “*groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups*”. For example, there are some species called **sibling species** that are reproductively isolated although they have extremely minute genetic differences. This definition assumes that a species cannot interbreed with other species due to a variety of isolating mechanisms that are behavioural, physiological, genetic, etc. Thus, according to the biological species concept, individuals within a species have a gene pool available for recombination through sexual reproduction within the group, and is not inhibited by pre- or post-mating reproductive isolation.

The main criticism of this definition is that it applies only to organism (i.e. life forms) that have sexual reproduction, and ignores the fact that some times gene flow occurs between closely related, sympatric species (species whose geographical ranges overlap). For example, significant gene exchange has happened between *bison* and *bus* (domestic cattle). Such occurrences violate the basic notion of the biological species concept. Nevertheless, this definition of a species continues to be widely used even today.

The phylogenetic species concept

Taxonomists (scientists who compare, classify and name organisms) tend to describe a species by studying their physical characteristics and behaviour, and also their genetic and chemical similarities and divergences as a result of evolution. Based on this concept Cracraft proposed the Phylogenetic Species Concept (PSC) in 1983. Here he defines a species as "the smallest diagnostic cluster of individual organisms within which there is parental pattern of ancestry and decent." However, it can be argued that a population, subspecies, stage or a morph can then be elevated to species status. Consequently, the number of species recognised becomes highly dependent on the analytical tools used. Even so, the PSC is considered as the most valuable tool for working taxonomists.

There are less widely accepted methods of defining a species such as:

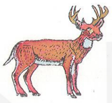
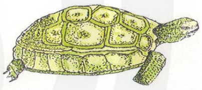
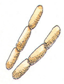
a) **The evolutionary species concept** which identifies a species as a "lineage (i.e. ancestor descendant sequence of population) evolving separately from others with its own unitary role and tendencies." This is similar to the PSC, without the criterion of interbreeding, but it is less practicable.

b) **The ecological species concept**: This identifies a species as a population that occupies a distinct ecological niche, whence its reproductive and general biological cohesion over time. This was never widely accepted and is very hard to operationalise.

Source: Primate taxonomy. Groves, 2001

Keystone species play critical role in the ecosystem they inhabit because they affect the abundance and health of many other species. Examples of keystone species include brown algae (Pacific coastal ecosystem), fruit eating bats (south-western deserts) and corals in tropical coastal waters. Their loss may endanger other species

Box 9.4: Known species of flora and fauna in the world

	4,500 species of mammals
	10,000 species of birds
	12,000 species of amphibians and reptiles
	22,000 species of fish
	400,000 species of invertebrates (excluding insects)
	960,000 species of insects, approximately 600,000 of which are beetles
	270,000 species of plants
	70,000 species of fungi
	4,000 species of bacteria
	5,000 species of viruses

There are different estimates of extant (i.e. currently existing) species on earth which range from about five to 100 million, but a figure of about **12.5 million** is the most widely accepted. Of these, only about **1.7 million species have been described** as yet. In terms of sheer numbers alone, **insects and micro-organisms are the most abundant life forms on earth**.

The distinct ecological importance of species supports functional diversity and has a direct bearing on the species composition of the site, and therefore on overall biodiversity. For example, a keystone species will be more important than other species for conserving overall biodiversity. Similarly, a species of tree in a tropical rainforest which supports a large number of endemic invertebrate fauna and provides food to vertebrates would make a greater contribution to global biodiversity than an alpine plant in a temperate country which has much less species dependant on it for survival.

9.3.3 Ecosystem Diversity

Ecosystem diversity means the variation between different types of ecosystems. Different species of animals, plants and micro-organisms interact with each other and their physical environment (such as water or minerals). Groups of organisms and their nonliving environment, and the interactions between them, form functional dynamic and complex units that are termed ecosystems. These systems help maintain life processes vital for organisms to survive on earth.

Different combinations of species and physical conditions (such as sunlight, climate, soil and water) and their varied interactions give rise to variation among ecosystems. For example, the physical conditions in a coral reef are very different to those in a tropical forest. Accordingly, the species in a coral reef differ from the species in a tropical forest.

Plant and animal communities make up many kinds of ecosystems we are familiar with today – from estuaries, ponds, marshes, coral reefs and other aquatic ecosystems to savannas, prairies, forests, deserts, mountaintops and other terrestrial ecosystems, including neighbourhood parks, school grounds and backyards.

Species are not evenly distributed around the globe. Some ecosystems such as tropical forests and coral reefs are very complex and host a large number of species. Other ecosystems such as deserts and arctic regions have less biodiversity but are equally important.

It is believed that there is a positive relationship between species diversity and an ecosystem's stability and resilience (i.e. ability to resist disturbances).

An ecosystem having higher diversity means the number of species and interactions between them which constitute the food web, is large (Fig.9.1a). In such a situation, the elimination of one species would have little effect on ecosystem balance. In sharp contrast, the number of species in the food web of a simple ecosystem is small (Fig.9.1b). So, loss of any one species has far more serious repercussions on the integrity of the ecosystem itself.

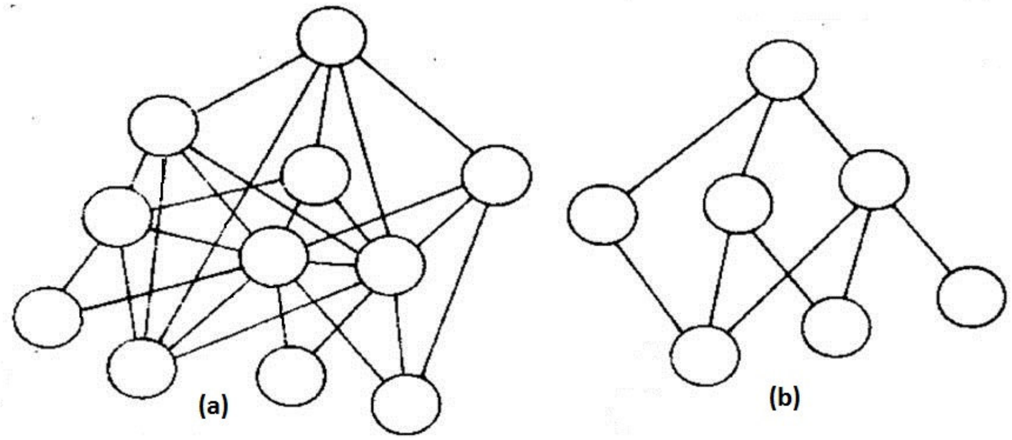


Fig. 9.1: The two illustrations give comparative picture of ecosystems with high a) and low b) species diversity. The circles represent organisms. Note the complex linkage in a, and only a few links in b. The increased numbers of links are believed to confer stability to the ecosystems.

9.3.4 Landscape Diversity

Landscape diversity is the complexity and diversity of landscape elements in composition, structure and function which refers not only to number of different patch types, patch size and patch shape within a landscape mosaic, but also to the spatial arrangement of different patch types and the connectivity. The more ecosystems exist within a landscape, the more resilient that landscape is, and the more services it has to offer its inhabitants.

The diversity of habitat over a total landscape is **gamma diversity.** Landscape diversity that includes patch diversity, landscape type diversity and pattern diversity may influence various ecological phenomena *viz*., nutrient cycling, species distribution, energy flows.

SAQ 2

a) How keystone species plays an important role in biodiversity conservation?

b) What is gamma diversity?

9.4 MEASURING BIODIVERSITY

Conservation and management of biodiversity require measurement of biodiversity because it is important to make choices about “what, where, and how” to conserve. Measurement can be considered at all three levels of biodiversity: genes, species and ecosystems. As they are all interrelated, it is difficult to talk about measures at one level while ignoring the others. It is also difficult to measure biological diversity because there are so many ways of measuring it, and the situation is made more complex because of problems associated with the interpretation of data resulting from the different forms of measurement.

9.4.1 Measuring Species Diversity

The measurement of species diversity provides an important preliminary assessment of overall biodiversity. There are many ways by which species diversity is measured i.e. species richness, taxonomic diversity, taxonomic uniqueness and species-diversity indices.

- **Species richness:** This is the most widely used measure of species diversity. In simple terms *it is a count of the total number of species in a given area*. It gives equal weightage to all species and does not take into account the number of individuals that represent a particular species. A large number of individuals of a single species will result in greater genetic diversity, and thus positively influence overall biodiversity. Complete counts of species richness of an area are rarely possible, so that the measure of species richness is often based on sampling smaller representative sites within the area to be assessed. Accuracy of sampling is thus important in estimating species richness of a given area.

To describe the complex spatial patterns of biodiversity, ecologists and biogeographers have found it useful to express species richness into four major categories:

1. **Point richness**
2. **Alpha (α) richness,**
3. **Beta (β) richness, and**
4. **Gamma (γ) richness**

Point richness refers to the number of species that can be found at a single point in space.

Alpha (α) richness refers to the number of species found in small, homogenous area. **Alpha diversity** refers to the diversity in a particular area or ecosystem and is usually expressed by the number of species (i.e. species richness) in that ecosystem.

Alpha diversity is characterised by several widespread patterns that are characteristic of most taxa and are strongly correlated with physical environmental gradients. For example,

- Marine and terrestrial environments in tropical regions have more species of higher taxonomic groups than those in higher latitude communities.

- Richness of species in terms of most taxa is positively correlated with habitat structural complexity.

- Structurally simple habitats like open oceans, grasslands, etc. generally support fewer species than structurally complex communities such as forests and coral reefs. In the open oceans maximum richness of most groups is found at depths between 2000-4000 m. In contrast coral species richness peaks at depths between 15-30 m because corals obtain their energy from photosynthetic organisms embedded in their tissues, and are thus confined to the photic zone.

- Island communities are poor in species than comparable mainland communities.

Beta (β) richness refers to the rate of change in species composition across habitats and **β diversity** refers to diversity between the ecosystems.

Gamma (γ) richness refers to the rate of change across larger landscape gradients and **gamma diversity** is a measure of the overall diversity for different ecosystems in a region. Hunter defines gamma diversity as "**geographic-scale species diversity**". Let us make this concept more clear to you by giving an example. Suppose we want to compare diversity of hypothetical species in different ecosystems say I, II and III (Table 9.1).

We can walk a transect in each of these three ecosystems and count the number of species we see, this gives us the alpha diversity for each ecosystem, e.g. α diversity of ecosystem I, II and III is 10,7, and 3 reap. Now, if we examine the change in species diversity between these ecosystems then we are measuring the β diversity, e.g. beta diversity between I and II is 7(representing 5 found in ecosystem I but not in ecosystem II plus 2 species found in ecosystem II but not in I), similarly β diversity between ecosystem II and III is 8 and between ecosystem I and III is 13.

The total number of species for the three ecosystems is 14, which represents the gamma diversity.

Table 9.1: Alpha, beta and gamma diversity for hypothetical species in three different ecosystems

Hypothetical species	Ecosystem-I	Ecosystem-II	Ecosystem-III
A	X		
B	X		
C	X		
D	X		
E	X		
F	X	X	
G	X	X	
H	X	X	
I	X	X	
J	X	X	
K		X	
L		X	X
M			X
N			X
Alpha diversity	10	7	3
Beta diversity	I vs. II (7)	II vs. III (8)	I vs. III (13)
Gamma diversity		14	

Taxonomic diversity

Taxonomic diversity is relative abundance of a species as well as the ancestor descendant relationships of species to each other. For example, an area with two species of mammals and one species of reptile has greater taxonomic diversity than an area of similar size with only three species of mammals although both have three species each. Similarly, an area with a large number of closely related species is not as diverse as distantly related. It has also been suggested that a site with a large number of higher taxa (which offer greater genetic variation) would possess more taxonomic diversity than a site with more species but less higher taxa.

- **Taxonomic uniqueness:** The concept of species richness in terms of numbers alone does not take into account the fact that the more distantly related a species is from others, the greater is its contribution to overall biodiversity. For example, two species of *Tuatara* (genus *Sphenodon*) living in New Zealand are the only extant members of the reptile order Rhynchocephalia. Their genetic make-up would, therefore, be unique and very different from their “closest” relatives. It can be expected that such species contribute more towards maintaining a high global biodiversity than species having a large number of very closely related species. Various measures are now being developed to take into account the taxonomic uniqueness of species when assessing biological diversity. For instance, a simple method of assigning taxonomic uniqueness to endemic species is based on the diversity of the genus and the family to which it (the genus) belongs.
- **Species diversity indices:** From an ecological point of view, species richness alone has limited value. More meaningful measures use the number of different species in a given area (species richness) as well as the relative abundance (in terms of numbers) of individuals in each species. For example, the Shannon-Wiener Index of diversity uses both species richness and the relative abundance of species in its computation of the diversity index.

Shannon-Wiener index

This diversity measure is based on information theory of measure of order (or disorder) within a particular system. For our uses, this order could be characterized by the number and/or the number of individuals in each species, within our sample plot.

By applying these numbers to the Shannon-Wiener equations we can determine what is referred to as the degree of uncertainty. With this number we can then specify our degree of diversity.

$$H' = -\sum_{i=1}^{3} (p_i)(\log_2 p_i)$$

where H' = Information content of sample, Index of species diversity or Degree of Uncertainty, s = Number of species, pi = proportion of total sample belonging to ith species.

Alternative Form

An alternative form for Shannon-Wiener index:

$$N_1 = 2^{H'}$$

or

$$N_1 = e^{H'}$$

where N_1 is the number of logarithms used to equally common species for the diversity H'. The equations vary depending on the type of the logarithms used to calculate H'.

Base conversion with Logarithms

To convert from known log bases to any other log base use

$$\log_b x = \frac{\log_e x}{\log_e b}$$

where **b** is the base value, **log *e*** is the natural logarithm and **x** is value to be transformed. For example to take a log base 2, you would use:

$$\log_2 x = \frac{\log_e x}{\log_e 2}$$

Measures of Evenness

The maximum Shannon-Wiener index for a given number of species can be calculated as:

$$H'_{\max} = \log_2 S$$

The minimum Shannon-Wiener index for a given data set can be calculated as:

$$H'_{\min} = \log N \left(\frac{N-S+1}{N}\right) [\log (N-S+1)]$$

where

S is the number of categories or species

N is the total number of observations.

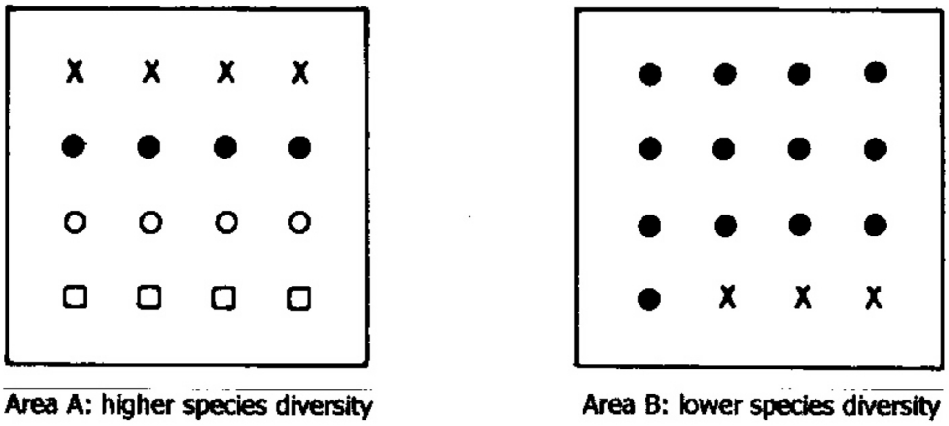
The evenness of the sample can be calculated by the following two equations:

$$J' = \frac{H'}{H'_{\max}}$$

or

$$Evenness = \frac{N_1}{S}$$

According to this index, Area A with four species with four individuals each will have greater species diversity than area B also with four species but with one having 13 individuals while the other three have only one individual each (Fig. 9.2).


Area A: higher species diversity

Area B: lower species diversity

Fig. 9.2: A diagram to show the species diversity in two different areas.

9.4.2 Measuring Genetic Diversity

Genetic diversity needs to be measured through some complicated processes as given below:

- **Protein electrophoresis:** This method is now being used to measure genetic diversity. Genes contain the information required to produce enzymes – which are proteins – and "dictate" the "code" to other cell organelles to do the actual production. Variations in the genetic information coding the production of enzymes will therefore show up in the differences of the protein enzymes that the genes "code" for. Protein electrophoresis thus shows the variations in the proteins produced, thereby indicating the diversity of genes that coded for them.
- **Restricted fragment polymorphism:** This method makes use of a group of enzymes termed restriction enzymes which recognise particular sequence of DNA and act as "molecular scissors" to cut at the beginning and end of these sequences. When DNA from one individual is cut this way, and the resulting fragments are subjected to electrophoresis, the fragments become aligned by length enabling the recognition of a pattern. The analysis of patterns from different individuals permits an assessment of variation in their DNA sequences. Measuring the differing frequencies of the various patterns in a population or species can indicate the genetic diversity within the group.
- **DNA fingerprinting:** This method makes use of a common, but peculiar, group of DNA sequences known as minisatellites. High levels of variation in the numbers of these repeated units are used in "DNA fingerprinting" to identify relationships that range from distantly related taxonomic groups to closely related individuals within a population.

9.4.3 Measuring Ecosystem Diversity

Measuring ecosystem diversity is not easy, and there is no definite index for its measurement. It is generally assessed by the measure of species diversity in an ecosystem, often based on the diversity of vegetation in a particular area. This may involve the assessment of the number of species in an area as well as their relative abundance. If all species have equal numbers, the area will be more diverse than one in which one, or few, species predominate. Also, an area with more size classes of the vegetation, different trophic levels (i.e. positions of different species in a set of linear feeding relationships) and taxonomic groups will be considered more diverse. Thus, a hypothetical ecosystem with ten species of plants only would be considered less diverse than an area with seven species of plants, two herbivores and one predator. Further, an area with relatively low species diversity, but having a large number of endemics (i.e. species limited to a particular area, such as a country) make an important contribution to overall biodiversity. For example, **small oceanic islands and continental montane regions have relatively low species diversity, but high levels of endemism**.

It also has to be borne in mind that the scale of measurement needs to be given serious consideration when comparing diversity between two different ecosystems. For example 1 m^2 of European chalk grassland can have much more plant species than a comparable area in an Amazonian rainforest! At the scale of 1 km^2, however, the situation will be quite the reverse.

Ecosystem diversity measures based on the species composition of flora, or fauna, or other ecosystem properties, are all equally justifiable: but measures based on different criteria tend to give different results. It is also important to note that diversity measures used for ecological units, such as ecosystems, assume that these units are basically the same in form throughout a wide area and in different places. In reality, however, this is rarely true. These diversity measures cannot, therefore, be effectively used for purposes of generalisation.

SAQ 3

List three ways by which species diversity is measured.

9.5 SUMMARY

Let us summarize what you have learnt so far:

- The term biological diversity was coined by Thomas Lovejoy in 1980 and the term biodiversity was coined by E.O. Wilson. Biodiversity is a measure of the relative diversity among organisms present in different ecosystems. Biodiversity is the totality of genes, species and ecosystems of a region.
- Biodiversity is diversity of genes and organisms for geneticists; diversity of population of organisms and species for biologists; diversity of durable interaction among species for ecologists.
- There are three levels of diversity i.e. **genetic**, **species** and **ecosystem**. All these levels are interacting and influencing the others.
- Genetic diversity underlies the differences among individuals of a given species. Genetic diversity allows a species to adapt to changing environmental condition. Genetic diversity within a species will increase with the number of individuals of a given species.
- Species diversity is the most visible component of biodiversity. It means the differences between species. There are about 12.5 million species in the World out of which 1.7 million species have been described.
- Variation between different types of ecosystems is called as ecosystem diversity. Different combinations of species and physical conditions and their varied interactions give rise to variation among ecosystems. Some ecosystems such as tropical forests and coral reefs are rich in diversity.
- Measuring biodiversity is very important as conservation and management of biodiversity is based on these measures. It is difficult to measure biological diversity because of the problem related to its interpretations.
- Species diversity can be measured by species richness, taxonomic diversity, taxonomic uniqueness and species diversity index.

- Genetic diversity can be measured by protein electrophoresis, restricted fragment polymorphism and DNA fingerprinting.
- Ecosystem diversity is based on the diversity of vegetation in a particular area. Some ecosystems (e.g. oceanic islands) have relatively low species diversity, but high levels of endemism.

9.6 TERMINAL QUESTIONS

1. By citing an ecosystem, (say tropical forest, or grassland) explain how different levels of diversity are interrelated.
2. Explain the importance of Shannon-Wiener index with reference to measuring species diversity.
3. Explain the processes used to measure genetic diversity.

9.6 ANSWERS

Self-Assessment Questions

1. a) Biological diversity is a *measure of the relative diversity among organisms present in different ecosystems*.

   b) E.O. Wilson and Thomas Lovejoy respectively.

3. a) A keystone species will be more important than other species for conserving overall biodiversity. Similarly, a species of tree in a tropical rainforest which supports a large number of endemic invertebrate fauna and provides food to vertebrates would make a greater contribution to global biodiversity than an alpine plant in a temperate country which has much less species dependant on it for survival.

   b) The diversity of habitat over a total landscape is **gamma diversity.**

4. Species richness, taxonomic diversity, taxonomic uniqueness and species-diversity indices.

Terminal Questions

1. Refer to Section 9.3.
2. Refer to Subsection 9.4.1.
3. Refer to Subsection 9.4.2.

UNIT 10

CONCEPT OF BIODIVERSITY-II

Structure

10.1 Introduction
    Objectives
10.2 Biodiversity as Products
    Food
    Wood
    Energy
    Raw Material for Industry
    Medicines and Drugs
    Ornamental Uses
10.3 Biodiversity as Services
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    Maintenance of Soil, Air and Water Quality
    Climate Regulation
    Drought and Flood Control
    Cycling of Nutrients
    Habitat
    Economic Value
    Spiritual/Cultural Value
    Scientific Use
    Recreation and Tourism
10.4 Causes of Biodiversity Loss
    Habitat Destruction
    Over Exploitation of Resources
    Hunting and Export
    Selective Destruction
    Pollution
    Pesticides
    Global Climate Change
    Invasive Species
    Domestication
10.5 Major Impacts of Biodiversity Loss
10.6 Biodiversity and Economics
    Valuation of Biodiversity
    Future Directions in Biodiversity Valuation
10.7 Summary
10.8 Terminal Questions
10.9 Answers

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10.1 INTRODUCTION

Biodiversity is multiple resource based offering us a range of products, materials and services. Our survival and well being of man-kind is directly dependent on biodiversity. Biodiversity produces goods and services for the most fundamental of our needs – clean air, fresh water, food, medicines and shelter. It also provides people with recreational, psychological, emotional and spiritual enjoyment. Some people believe we should protect and restore biodiversity because of its benefits to us. Others believe that we have a moral responsibility to protect biodiversity simply because all organisms have value, whether or not we understand their benefits to us.

In this unit, you will study about importance of biodiversity as products (food, energy, medicines, drugs) and as services (ecosystem regulation).

As many as 500 million kinds of plants, animals and microorganisms have made earth their home since life began, over 3.5 billion years ago. Presently, it is believed that there are only 5 to 10 million species alive. We, however, do not have an exact figure because there are many areas on the earth that are biologically unexplored. Tropical rain forests are examples of such areas, about which we know little. And a majority of the organisms living there remain to be identified.

A few species naturally become extinct over time and it is believed that however, during certain periods of geological time, great numbers have been lost relatively quickly – on the scale of thousands of years. Scientists have documented five mass extinctions since the emergence of life on this planet some 3.8 billion years ago.

Objectives

After studying this unit, you should be able to:

- ❖ explain the importance of biodiversity in providing goods and services;
- ❖ describe medicinal and ornamental uses of biodiversity;
- ❖ appreciate the significance of biodiversity in ecosystem balancing by nutrient cycling, climate regulation, drought and food control, air and water purification;
- ❖ explain the use of biodiversity in recreation and tourism, scientific experiments;
- ❖ explain the factors affecting loss of global biodiversity;
- ❖ discuss the major impacts of biodiversity loss; and
- ❖ explain the valuation of biodiversity.

10.2 BIODIVERSITY AS PRODUCTS

Individual components of biodiversity provide an unbelievable wide range of products that are used to enhance the lives of people in all countries of the world. It is the diversity of the resource base, due to the existence of a range of biological resources that has enabled the present high quality of life for humans. Biodiversity underlies the wealth of raw materials for:

- direct harvesting of food from the wild and from cultivation ranging from basic subsistence farming to sophisticated agricultural systems,

- medicines to combat diseases and pests that threaten human health, agriculture and animal husbandry,
- industry that provides humans with essential and luxury items including clothing, construction, timber and wood products, etc.

You will study about these in following subsections:

10.2.1 Food

Simply stated, our food comes directly or indirectly from plants. More than 90 percent of the calories consumed by people worldwide come from 80 plant species. Fruits, nuts, mushroom, honey, spices and other foods that humans and wild life consume originate from natural ecosystems.

A recently discovered tropical species – the winged beans is a potential source of food. Every part of this plant is edible. Its leaves taste like spinach, young pods are like green beans, young seeds like peas, mature seeds like soybeans, and its underground stems are like potatoes and are rich in proteins. It is a fast growing nodule-bearing plant that enriches soil with fixed nitrogen. Such plants and others like them from the wild give hope to feed growing millions.

Plant food

Due to the modern high yielding varieties of crops and the homogenization of food habits across the world, there has been an increasing reliance on a few edible species. Consequently of the estimated 240,000 species of flowering plants worldwide, only about 3,000 are used somewhat consistently and considered edible (i.e. suitable as food). There are records to show that approximately 80,000 edible plants have been used at one time or another in human history although at present only about 150 have ever been cultivated on a large scale and a mere 10 to 20 provide 80 to 90% of the world's calories today.

People obtain a wide array of food items from agricultural systems, forests, mangrove areas, the sea, estuaries and lagoons for subsistence and commercial uses. These include a range of cereals and millets, legumes, oilseeds, vegetables, mushrooms, yams, spices and condiments, fruits and berries. A considerable part of daily food intake of rural (especially tribal) communities comes from the wild. These include edible greens and seeds, lichen species, spice and flavoring agents, seaweeds, floral species utilized primarily as famine foods, rhizomes and tubers, fruits, shoots, mushrooms and sap (e.g. kitul sap that is used to make a local sweetener).

Animal food

Domesticated animals provide much of the world's meat products today, but wildlife still constitutes to be an important source of food of many rural communities. The International Trade in Wildlife for 'game meat' is carried out on a large scale due to high economic returns as revealed by customs reports. For instance, green turtles (*Chelonia mydas*) have been exported from the Caribbean and the Indian Ocean to Europe, and elsewhere, for a long time to satisfy the gourmet (i.e. luxury food) trade, although this is now prohibited by the Convention on International Trade in Endangered Species (CITES).

Invertebrates too are an important source of food for people throughout the world. There are many species of marine molluscs (e.g. oysters, cuttlefish, squid) and arthropods (e.g. crabs, shrimps, lobsters) that are used as food and are economically important. Terrestrial species in these groups are also popular in some regions. For instance, the Giant African Land Snail (genus *Achatina*), believed to have a protein value similar to beef, is eaten by many people in different parts of Africa. Large scale of frog legs were sent to Paris as these are considered as delicacy in Paris. But frogs play a very important role in mosquito control hence their export has been prohibited now.

A total of about 500 species of insects are consumed worldwide. The most widely used species are termites, that can be found in very large numbers in a given location or species that swarm periodically. The hymenopterans (bees, wasps and ants) are very important in terms of food, especially bee honey and the bee brood collected with the honey.

Global fish production is the largest source of protein from both wild and domestic animals in the world, as it exceeds the food obtained from cattle, sheep, poultry or eggs. Among the most common in the fish catch around the Indian subcontinent are sardines (especially oil sardine), Indian mackerel and prawns.

Genetic resources

Genetic diversity or the gene pools are important for promoting and ensuring high agricultural yield.

Genetic diversity provides crops with the flexibility needed for them to survive changes in the environment, which is especially important in view of the predicted global climate change in the foreseeable future. Crop diversification has resulted mainly due to the processes of natural selection in response to new ecological conditions, selection by farmers for particular characteristics over long periods of cultivation, and colonial expansion that resulted in the spread of crop species between countries and continents.

Wild relatives of crop species are important storehouses of crop genetic diversity. For example, farmlands in the Himalayan foothills of north-east India contain a large number of primitive rice cultivars that show resistance to major pests and diseases including bacterial blight, viruses, gall midge and the stem borer. An example is that a minimum of 50,000 varieties of rice have been grown in India until the very recent past. The high crop diversity is not accidental but due to the result of careful selection and even cross-breeding, over centuries, by the regions farmers to contend with different environmental conditions and needs.

The predominant strain of rice grown in Asia, for instance was devastated by a virus, but one wild strain from India had genes for resistance. Through intensive breeding, a resistant hybrid was created which is now widely grown.

Biotechnology and the resultant GMOs and LMOs

Techniques that use gene modification through (a) recombinant DNA technology and (b) cellular techniques of introducing DNA into an organism has opened up new vistas to the agriculture sector, food processing industry and human health care. These modern techniques now enable the transferring of genes between species that is now possible through normal processes such as sexual reproduction. Such techniques used in biotechnology give rise to **Genetically Modified Organisms** (GMOs) and **Living Modified Organisms** (LMOs). For example a crop species such as tomato can have genes of an animal species introduced into its genetic makeup to increase its size or crop yields, or to provide it with resistance to disease causing organisms or pests.

Even so, there is increasing concern about the risks of biotechnology that produces GMOs and LMOs as they can have severe adverse effects on the natural environment and on human health, especially as some of the genes introduced are from viruses and bacteria.

Thus, adequate checks and balances, as well as specific guidelines, are required to control the technology and the handling, transfer and release of genetically modified organisms. This aspect is currently being addressed at the international level through Article 19 of the Convention on Biological Diversity (CBD) and the related legally binding International Protocol on Biosafety that was adopted in January 2000.

10.2.2 Wood

Wood has been important to human beings for many years. Over hundreds of years, people have destroyed vast areas of woodland. The great forests that once covered Europe have been cut and bare areas can be seen that were once covered by trees. Many people all over the world are saving the world's forests. New trees are planted to take the place of those cut down.

Wood is a material found as the primary content of the stems of woody plants, especially trees, and also shrubs. Wood is one of the most important building materials. It is used for beams, floors, doors, furniture, industries also use it for making furniture, boxes, toys, boats and hundreds of other products. Wood is commonly classified as either hardwood or softwood. The wood from conifers (e.g. pine) is called **softwood** and the wood from broad-leaved trees (e.g. oak) is called **hardwood**. Most paper is made from softwood trees such as fir, pine and spruce. About 70% of the world's timber needs are met by softwoods derived from the coniferous trees. Some conifers mature in 30-50 years. Timber is the greatest resource of the rain forest. There is an increasing demand for hardwood timber and its costs are rising. Many hardwood trees need about 100 years to reach maturity. The trees are being felled faster than they can be replaced. Table 10.1 provides a list of commonly used timber species.

Table 10.1: List of timber yielding tree species.

No.	Softwoods (conifers)	Hardwoods (angiosperms)
1.	Cedar (E*drus*)	Afzelia (*Afzelia*)
2.	Cypress (*Chamaecyparis*)	Agba
3.	Douglas-fir (*Pseudotsuga*)	Albizia (*Albizia*)
4.	Fir (*Abies*)	Alder (*Alnus*)
5.	Hemlock (*Tsuga*)	Applewood or wild apple (*Malus*)
6.	Larch (*Larix*)	Ash (*Fraxinus*)
7.	Pine (*Pinus*)	Aspen (*Populus*)
8.	Redceedar (*Thuja plicate*)	Ayan (*Distemonanthus benthamianus*)
9.	Redwood (*Sequoia sempervirens*)	Balsa (*Ochroma pyramidale*)
10.	Spruce (*Picea*)	Basswood (*Tilia americana*)

11.	Sugi (*Cryptomeria japonica*)	Beech (*Fagus*)
12.	Yew	Birch (*Betula*)
		Cherry (*Prunus*)
		Coralwood (*Guilbourtia spp.*)
		Ebony (*Diospyros*)
		Elm
		Eucalyptus (*Eucalyptus*)
		Gum
		Hickory (*Carya*)
		Mahogany
		Maple (*Acer*)
		Oak (*Quercus*)
		Rosewood (*Dalbergia spp.*)
		Sandalwood (*Santalum album*)
		Teak (*Tectona grandis*)
		Willow (*Salix*)

10.2.3 Energy

In many countries of Asia biomass contributes largely as a source of primary energy. People in rural areas at the peripheries of forests, continue to collect fuel wood from adjacent forests. India consumes 15% of the world energy. The source of energy are renewable and non-renewable (commercial energy). Energy is being used for domestic and industrial purposes. Non-renewable energy sources include coal, petrol, diesel, kerosene etc. The intensity of energy extraction, production and use of these resources have resulted in the destruction of environment through pollution – The consumption rate of these resources is twice than production. Hence renewable energy sources are being used extensively in India. Major renewable energy sources are solar energy, wind energy and biomass.

India is considered as world leader in renewable energy resources. It ranks first in the use of solar cookers (4.6 lakh) and biomass (mh 27).

Relatively poor societies are entirely dependent on firewood and other biomass for their energy needs particularly the forest dwellers and forest tribes. In India, biomass combustion includes fuel for domestic cooking in stoves (hence referred to as biofuel). Biofuels used in rural India include wood, crop waste and dung cake.

The only reported biofuel used in urban areas is wood. The largest contribution to biofuel consumption is from Uttar Pradesh (13%, dung cake – 7%, fuel wood – 4%) followed by Andhra Pradesh (11%, fuel wood – 5% crop waste – 4%), Bihar (10%, fuel wood – 7%, dung cake – 1%) and Madhya Pradesh (9%, fuel wood – 7%, dung cake – 1%). Forest biomass burning is found to be high in Andhra Pradesh and east Madhya Pradesh.

Dendrothermal power (energy from plant material) is now increasingly viewed as an alternative source of energy, in preference to fossil fuels that result in the release of green house gases that add to the impacts of climate change.

10.2.4 Raw Material for Industry

The industry, producing goods and services, relies and impacts on biodiversity directly. Much of the raw material that goes into industrial operations is a by-product of biodiversity. The trees, the animal organs, the microbial culture are a few examples of sources of raw materials. Plants and animals provide a wide variety of resources used in industry and commerce for both domestic and commercial markets. As many as 2000 plant species throughout the world are known for their economic importance. The building, furniture and paper making industries are dependent on more than one hundred different species of trees. Cotton, flax, hemp and jute provide fibre for manufacture of textiles, ropes and other articles (Fig. 10.1). For example, plant extracts are used in the manufacture of glues, soaps, cosmetics, dyes, paints, plastics, lubricants and polishes. Household implements such as needles and hooks are made from horns, scales and fins of animal origin. Fat from wild species (e.g. marine mammals and sharks) is used to produce a range of oils. Wildlife products such as cane and other lianas, bark, fur, hides, scales, bones and feathers are used to make a variety of clothing and utensils.

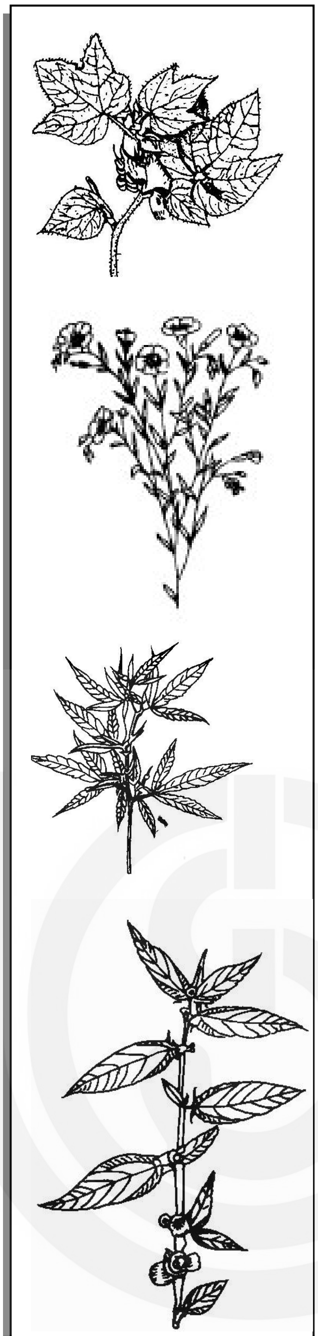

Fig. 10.1: The important sources of fibres a) Cotton - from seed coat; b-d) Flax, Hemp and Jute respectively, fibres are extracted from their stems.

The silk industry is dependent on several species of silkworms, but the finest silk is obtained from the mulberry silk moth, which is now domesticated. The moth pupae which are left after extracting the silk during sericulture, are used to produce soap and cosmetics. Cochineal, a brilliant red colouring agent formerly widely used in the food and cloth industries, is also an insect product obtained from the semi-domesticated form of a scale insect.

You will study in next section that pharmaceutical industry is directly dependent on biodiversity. Most of the drugs used today are from plant or animal sources. A species destroyed may mean an opportunity lost to cure a serious disease. Who knows the cure of AIDS may just be down the road coming from a root of remote plant.

Rattans as raw material

Rattans provide an economically important bioresource from tropical forests. There are about 600 species of rattans worldwide, of which most are found in South and Southeast Asia. The Phillippines, China, Indonesia, India, Sri Lanka and Thailand are the main countries that engage in the rattans industry. Rattans are used to produce cane furniture for the international market while at the community level they are used to produce baskets, boxes, mats, domestic utensils, fish traps, dyes and medicines. Overall, the industry provides full-time employment for at least half a million people around the world.

The rattans industry relies almost entirely on wild stocks, with about 90% of the world's raw material being extracted from the wild. As such, over exploitation and habitat destruction has caused a decline of the commonly used commercial rattan species. The highest diversity of rattans occurs in the

Malay Peninsula, which has about 104 species of which about 38% are endemic and most are considered to be threatened. In Sri Lanka too, forests continue to provide raw material for the cottage scale rattan and bamboo handicraft industry, which has about 2200 craftsmen and 700 families dependant on it for cash income. Interestingly, different species of rattans are used to produce different domestic utensils indicating the value of species diversity.

Unfortunately in a planet where six billion people's needs have to the fulfilled, raw materials are being used faster than they can be replenished. The pace of industrial activity cannot be slowed down because of obvious reasons but it should be kept in mind that industrial operations should be biodiversity friendly.

Rattans are climbing palms that provide the raw material for the cane-furniture industry. Sometimes confused with bamboo, canes can usually be distinguished because they are solid whereas bamboos are almost always hollow. Rattans are particularly abundant in South-east Asia and the Malay Archipelago.

10.2.5 Medicines and Drugs

The World Health Organization (WHO) has listed over 21,000 plant names (including synonyms) that have recorded medical uses around the world. However, very few of these medicinal plants have as yet been subject to scientific investigation, and only about 5,000 species of higher plants have been fully investigated as potential sources of new drugs to date. At present about 90 species of higher plants have yielded a total of 119 pure chemical substances that are used in medicines throughout the world. An estimated 4.5 billion people (about 80 percent of the world's population) still use plants as their primary source of medicine. The use of most of these medicines is based on ancestral knowledge. Even in today's high-tech society whose most things can be synthesized in laboratories of modern medicines prescribed in good percentage are of biotic origin. Numerous life saving drugs have been isolated from flowering plants. Close to 30 percent of all pharmaceuticals on the market to day are developed from plants and animals.

In most biodiversity rich developing countries the genetic resources of medicinal plants have been inadequately assessed and there is danger that the existing indigenous knowledge about the medicinal properties of plants will be lost with a shift towards western medicines. It is therefore important to document the different medicinal species and their uses for posterity.

A wider range of plant species is used for medicinal purposes at the local level in many countries of world, and about 80% of people living in developing countries continue to rely on traditional medicines that use plants or plant extracts. Most of the plants used in indigenous medicines are collected from forests. In China more than 5000 species are used in traditional medicines alone. Medicinal plant species are largely extracted from the wild even in developed countries and relatively few are cultivated as crop plants.

1. A large number of important drugs are derived from plants. For example **Tubocuranin**, derived from plant-based curare, is used as a muscle relaxant during surgery.

2. **Curianol**, a Guyanes fish poison is used in heart operations. It has also been identified that over 1,400 tropical forest plants contain substances that can fight cancer.

3. The Rosy Periwinkle *Catharanthus roseus,* has been used for generations by tribal medicinal healers in Madagascar which is its country of origin.

4. **Digitoxin**, the most widely used cardiac stimulant is obtained directly from the foxglove *Digitalis* (Fig. 10.2).

5. Antibiotics such as penicillin are extracted from fungi and from such unlikely sources as the African clawed frog's skin.

Plants yielding pharmaceutical compounds are listed in Table 10.2 and activity of selected top-selling botanical medicines is listed in Table 10.3.

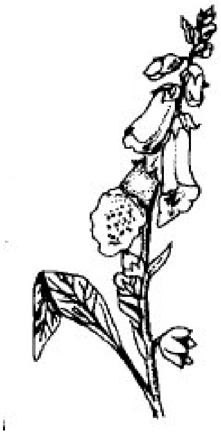

Fig. 10.2: A part of the foxglove plant – the source of digitoxin.

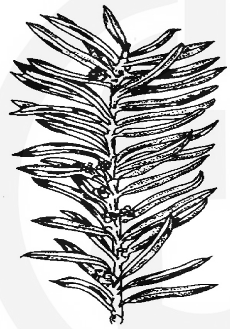

Fig. 10.3: A shoot of *Taxus baccata*, the source of taxol.

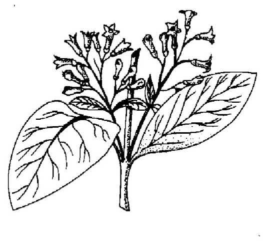

Fig. 10.4: A branch of *Cinchona* tree. Qunine is extracted from its bark

Table 10.2: Examples of plants yielding pharmaceutical compounds.

Catharanthus roseus	This species yielded the alkaloids vincristine and vinblastine. Traditionally used by various cultures for the treatment of diabetes, these compounds were first discovered as part of an investigation of the plant as a possible oral hypoglycemic. Originally native to Madagascar, this species is now widespread and common. The vinca alkaloids are used in the treatment of childhood leukemia and Hodgkin's disease.
***Podophyllum* spp.**	These species were long used by indigenous people in Americea and Asia, including for the treatment of skin cancers and warts. The combination of cumulative demand and loss of the habitat led to the placement of *Podophyllum hexandrum* on Appendix II of the CITES list in January 1990.
Taxus brevifolia (Fig. 10.3)	Collected in Washington State, The needles of *Taxus baccata*, in which paclitaxel is found, are used in traditional Ayurvedic medicines, with one reported use being for various types of cancer.
Camptotheca acuminata	This species is an ornamental tree in China, and has yielded the clinically active agents topotecan, irinotecan, and 9-aminocamptothecin, which are semisynthetically derived from camptothecin. Camptothecin is now marketed under the generic name 'Topotecan' and the brand name 'Navelbine' by SKB.
Chondrodendron tomentosum	This species, used by indigenous people of South America in an arrow poison known as curare is used as model for a series of neuromuscular-blocking agents.
Rauwolfia serpentine	Known as the Indian snakeroot, with a long history of traditional medical use, including for the treatment of mental disorder, snake bites, and as a tranquiliser, this species yields the antihypertensive compound reserpine. The Indian Ministry for Environment and Forests estimated sales of antihypertensives derived from the Indian snakeroot at more than US$260 million in 1994.
***Chincona* spp.** (Fig. 10.4)	The bark of this species yields quinine, a treatment for malaria. In the 1940s the principal alkaloids were isolated and synthesized for the pharmaceutical market, but its use in international markets had been established hundreds of years earlier.

Source: Cragg et al, 1997, Sheldon et al, 1997.

Table 10.3: Claimed activity of selected top-selling botanical medicines.

Product	Plant part	Activity
Ginseng	root	increases energy and sex drive
Siberian ginseng	root	defuses nervous tension and fights fatigue
Kava	root	combats anxiety and stress
Green tea	leaves	a powerful anti-oxidant and cholesterol-reducer
Milk thistle	fruit	protects from toxins – e.g. alcohol, pesticides
St. John’s wort	herb	anti-depressent
Psyllium	seeds	anti-constipation; helps in weight loss
Hawthorn	fruit	lowers blood pressure and fights arthritis
Saw palmetto	seeds	treats prostate problems
Valerian	root	relieves insomnia, anxiety, menstrual cramps, headaches
Liquorice	root	treats ulcers and stomach disorders
Wild yam	roots	alleviates PMS and menopausal symptoms
Aloe	leaves	treats wounds and skin problems
Camomile	flowers	alleviates moods and skin problems; calming
Feverfew	leaves	relieves migraine headaches
Bilberry	leaves	improves eyesight
Cranberry	fruit	keeps the urinary tract healthy
Garlic cholesterol	bulb	boosts the immune system; lowers
Calendula	flowers	soothes skin; fights bacterial, viral and fungal infections
Echinacea	roots, flowers	boosts immune system; prevents colds
Ginger	rhizomes	treats nausea; inflamed joints
Elderberry	flowers, fruit	remedy for head colds
Ginkgo	leaves	improves energy, mood, and brain function

Animals and biomedical uses

Animal products too are widely used in medicines by traditional societies, and in some urbanized societies that believe in traditional animal-based remedies. Examples of such products are dried lizards of several species, the genitalia of dolphins, fox fur, musk (from musk deer *Moschus* spp.), bears, gall bladders, tiger bones, rhino horn and many other parts of wild animals that are sold for medicinal purposes. Records indicate that the international trade in medicinal products derived from deer – especially, another tendons and musk is calculated to be worth around US $ 30 million a year!

The use of leeches for medical purposes can be traced back to the Greeks in the 2nd century B.C. Today, these live animals are used during micro-surgery. The sucking action and substances (e.g. anticoagulants) produced by leeches during feeding assist to ensure the survival of accidentally severed body parts, such as fingers and ears, after re-attachment.

Gorgonids yield chemicals like prostaglandins, medically useful for birth control, prevention of peptic ulcers, treatment of asthma, regulation of blood pressure, etc. Sponges are used to obtain substances with biomedical properties. Live animals, particularly primates, are used as experimental animals in the biomedical trade. Commonly used species in the past were the rhesus macaque (*Macaca mulatta*) and the crab eating macaque (*Macaca fascicularis*). Other species used in biomedical research even today are the squirrel monkeys (*Saimiri* spp.), marmosets (*Saguinus* spp.), the night monkey (*Aotus trivigatus*) and the chimpanzee (*Pan troglodytes*).

Micro-organisms in medicines

In terms of western medicines, over 3000 antibiotics – including penicillin and tetracycline – are obtained from micro-organisms. Another product of micro-organisms i.e. cyclosporin was developed from a soil fungus. It revolutionized heart and kidney transplant surgery by suppressing immense reactions. Many micro-organisms have their own antibiotics and scientists have not yet been able to fully identify their potential uses. Biotechnology can now help to isolate useful genes and transfer them to different species to produce substances such as enzymes required in large quantities for curative purposes. Unicellular bacteria also produce the antibiotics such as gramicidin, olymyxin B and bacitracin respectively. Some micro-organisms (fungi, actinomycetes and bacteria) are used to transform chemically synthesized steroid hormones to resemble natural hormones for clinical use.

Bio-insecticides, bio-pesticides and bio-fertilisers

A large number of plants are used for bio-pesticides and bio-fertilizers. Several plant species are used as insecticides against aphids and larvae of insect pests: for insects like blister beetles and termites; chilli is used for pests that affect storage and neem (*Azadirachta indica*) is used as a bio-pesticide. Storing of wheat and barley grains with cowdung ashes also prevents insect attacks, the oil cake of *Madhuca longifolia* ach. and the oil and leaves of *Pongamia pinnata* are used for insecticidal purposes. There are accounts of how jowar grains have been stored for more than 30 years by sealing them between layers of neem leaves in bins and buried in a 12 ft. deep pit. (The Statesman, 22.3.92 cited in the Indian NBSAP, draft in 2002).

10.2.6 Ornamental Uses

As with food crops, the “discovery, domestication and cultivation” of ornamental plants have a long history. There is indication that lilies were cultivated in China for both medicinal and decorative purposes for over two thousand years. Roses, lilies, violets, anemones, and lavender have been grown as garden plants in Europe since the time of the Roman Empire. At present the diversity of decorative plant species that are cultivated is greater than the diversity of food plants that are commonly grown around the world. In the UK alone an estimated 3,000 species, and a wide range of cultivars and hybrids, are cultivated for ornamental purposes. As “novelty and variety” are important in the horticultural market, plant biodiversity is the key to this industry as it permits the addition of new species or varieties periodically.

Ornamental plants are an important commodity in international trade due to the expanding market. As such, wild species of horticultural value are under threat around the world, due to both habitat destruction and direct exploitation for local and international trade. Important plants of ornamentals trade are: species with bulbs, orchids, cacti and other succulent plants, cycads and insectivorous plants. Over 5,000 species of orchids are recorded in CITES trade statistics during the period 1983-1989. *Dendrobium* is the most heavily traded genus of orchid exported from Thailand. Sri Lanka also has about 170 species of plants of ornamental value of which 74 are endemic.

Many wildlife products are valued for their ornamental, decorative or ceremonial purposes. Examples are ivory from elephants, tortoise shell (derived from the hawsbill turtle *Eretmochelys imbricata*) and furs. Ivory was much in demand for production of a variety of jewellery and artifacts in the past. Reptile leather from crocodiles, lizards and snakes has quite a high demand for manufacture of shoes and fancy goods.

Furs from the felix (i.e. cat) family for export are obtained from many species including the leopard, lynx, ocelot, little spotted cat, margay and the leopard cat (*Felis bengalensis*). There is high demand for these skins from Europe and Japan, although the overall market demand for these items has decreased due to the reduced popularity of furs as fashion items.

Bird feathers and some primate skins (e.g. black and white colobus) are used as items of adornment in many parts of the world, sometimes to indicated status of hierarchy. The skins of the black and white monkey (*Colobus guereza*) are used to make cloaks and head dresses for native people, and they are in demand for production of rugs and coats for the international trade.

SAQ 1

a) List five important plants having medicinal value.

b) List *five* important plants yielding pharmaceutical compounds.

c) List two differences between soft and hard wood.

10.3 BIODIVERSITY AS SERVICES

Biodiversity provides us with life-sustaining services. As discussed below, these ecosystem services have a much higher value than most people realize.

At the ecosystem level, biodiversity provides the conditions and the process that sustain the global economy and an existence as a species.

Individual species within ecosystems as well as ecosystems as a whole, are vital to human society as you will study in the following subsections. Even the most obscure organisms in an ecosystem are worth conserving.

10.3.1 Pollination

Many flowering plants rely on animals such as bees, butterflies, moths, wasps, beetles, birds, and bats for pollination to produce fruit. Thirty percent of our food crops, including almonds, apples, blueberries, cherries, and chocolate, rely on the free services of pollinators. Feed crops like alfalfa and hay for domesticated animals also depend on pollinators, and many wild plants such as fig trees that provide food and shelter for animals depend on pollinators. But pollinators, including the managed honeybee colonies used extensively in U.S. agriculture are threatened. Increasingly fragmented and degraded habitat, pesticides, and the introduction of diseases and non-native species are causing some pollinator populations to decline. Imagine farmers having to hand-pollinate their crops if we lose natural pollinators.

10.3.2 Maintenance of Soil, Air and Water Quality

Biodiversity maintains the air we breathe and the water we drink. Green plants purify our air and our water by taking in carbon dioxide, regulating water vapour, releasing oxygen, and cycling nutrients. Through photosynthesis, trees and other plants give off oxygen that helps maintain atmosphere. As a result of these processes, plants play a crucial role in maintaining the planet’s water cycle. Wetlands and the vast array of bacteria and other microscopic species they house also act as water filters.

The activities of microbial and animal species – including bacteria, algae, fungi, mites, millipedes and worms – condition soils, bring organic matter, and release essential nutrients to plants. These processes play a key role in the cycling of such crucial elements e.g. nitrogen, carbon and phosphorous between the living and non-living parts of the biosphere.

Wetland ecosystems (swamps, marshes, etc.) absorb and recycle essential nutrients, treat sewage, and cleanse wastes. In estuaries molluscs remove nutrients from the water, helping to prevent over-enrichment and its attendant problems, such as eutrophication arising from fertilizer run-off. Trees and forest soils purify water that flows through forest ecosystems. In preventing soils from being washed away, soil protection by forests also prevent the harmful siltation of rivers from erosion and landslides.

10.3.3 Climate Regulation

By giving off moisture through their leaves and providing shade, plants help keep us and other animals cool. Forests are especially good climate modifiers. Forests act as insulators helping to mitigate the impacts of freezing temperatures. As trees and other plants in forests release oxygen and take up carbon dioxide (CO_2) – the most prevalent greenhouse gas – the forests store carbon and help reduce global warming. So do oceans as they interact with the atmosphere. Algae living in the ocean take up carbon dioxide, and ocean currents and winds help control the world’s climate.

10.3.4 Drought and Flood Control

Forests, grasslands and wetland protect landscapes against erosion floods and landslides through the binding action of plant roots. The root systems of plants hold soils in place, preventing erosion and mudslides. Plants also hold moisture in soils and thereby help reduce the effects of drought. Lands that have been deforested and cleared, have little ability to hold water. These natural drought and flood control services are particularly important to people living along rivers and coastlines and for people in arid regions. Ecosystems bordering regularly flooding rivers (e.g. wetlands) absorb excess waters and thus reduce the damage caused. Certain coastal ecosystems (salt marshes, mangrove forests) prevent the erosion of coastlines.

10.3.5 Cycling of Nutrients

Pick up just a tiny bit of soil and you will discover a whole new world. Researchers have found that one pinch of soil may contain more than 30,000 protozoa, 50,000 algae, 400,000 fungi and billions of individual bacteria in addition to larger organisms like worms, insects and mites also live in the soil. These organisms break down dead plants and animals and recycle the nutrients into organic materials that enrich the soil. The movement of elements such as nitrogen, sulphur and phosphorus between different forms as they pass through the food chain. The elements cycle between gas forms and compounds which are found in soil and living organisms. For example, nitrogen cycle is heavily reliant on bacteria and involves the formation of nitrates (needed for making proteins which are the functional molecules in all organisms) from atmospheric nitrogen and then the break down of nitrogen compounds to nitrogen gas. The nitrogen cycle is an important part of soil formation and soil fertility.

10.3.6 Habitat

Natural ecosystems provide habitat for the world’s species. Forests, coral reefs and deep ocean bottoms house many species. Wetlands, through their mix of aquatic and terrestrial environments, nourish and shelter thousands of bird, fish and other animal species. Estuaries, where the currents and tides of salt water and fresh water meet, are the world’s nurseries for many of the aquatic species we consume, including fish and shellfish such as clams and crabs. Lakes and rivers, for example, constitute only 0.01 percent of the planet’s water, but they contain a quarter of all known species. Even open spaces in cities and towns support significant biodiversity.

10.3.7 Economic Value

Biodiversity serves as an income generating activity for countries around the world. Many people visit forests, beaches, mountains, grasslands, lakes, ponds, estuaries and streams for extended vacations or for shorter periods for relaxation. More than 130 million people visit U.S. national parks each year, and millions of dollars are spent annually on nature activities such as hiking, camping, fishing, hunting, whale watching and wildlife photography. Around the world the number of ecotourists, people travelling to enjoy nature and various cultures, is increasing. You have studied in detail about economic aspect of biodiversity in Unit 6 of this course.

10.3.8 Spiritual/Cultural Value

It is no mystery why people are prepared to spend so much towards the nature. Human beings instinctively desire aesthetic and spiritual satisfaction from biodiversity. Our emotional well being is enhanced in the proximity of natural beauty. The umbilical cord between humans and biodiversity is reflected in art, religion and traditions of human cultures: a spiritual heritage that will be lost for all time if nature is continued to be destroyed.

10.3.9 Scientific Use

Nature is a major source of inspiration for scientific thought and the subject of many scientific studies. Biodiversity which constitutes the whole of "living" nature has a profound "scientific value" in all cultures. The 'life-sciences' including agriculture, medicines, biotechnology and their varied applications pertaining to conservation, scientific insight and discoveries are based on the observations and study of nature/ plants, animals and their habitats.

10.3.10 Recreation and Tourism

Biodiversity has been always of enormous recreational and aesthetic value. Many people are willing to pay for the pleasure they derive from wildlife by making special excursions to view them and to watch them on film or television. For many developing countries biodiversity as a non-consumptive resource can be best justified by the money earned through tourists who are willing to pay to observe wild animals in their natural habitat, as this brings in much-needed foreign exchange to the host country. It has been estimated that each visitor pays almost US$200 to spend an hour with the wild Mountain gorillas in Rwanda, bringing in about US$1 million per year to the country as direct park revenue. The high diversity of the parade of wildlife is the primary draw of people to some popular tourist areas such as East and Southern Africa, the Galapagos islands and the Great Barrier Reef of Australia.

The growing market for enjoyment of wildlife and wild habitats is one of the important trends in the tourist industry in recent times, and ecotourism is gaining importance in many parts of the world. This is one way by which biodiversity contributes directly to the national economy in the form of revenue as well as jobs to local communities.

SAQ 2

How does biodiversity help in climate regulation?

In this unit, you have studied that biodiversity of ecosystems whether terrestrial or aquatic, have similar values in providing goods or services to human beings (Table 10.4).

Table 10.4: Goods and services provided by different ecosystems

Ecosystem	Goods	Services
Terrestrial	• Food crops • Fibre crops	• Maintain limited watershed functions (infiltration, flow control, partial soil protection)

	• crop as genetic resources	• Provide habitat for birds, pollinators, soil organisms important to agriculture • Sequester atmospheric carbon • Provide employment
Coastal ecosystems	• Fish and shellfish • Fishmeal (animal feed) • Seaweeds (for food and industrial use) • Salt • Genetic resources	• Moderate storm impacts (mangroves; barrier islands) • Provide wildlife (marine and terrestrial) habitat • Maintain biodiversity • Dilute and treat wastes • Provide harbour and transportation routes • Provide human and wildlife habitat • Provide employment • Contribute aesthetic beauty and provide recreation
Forest ecosystems	• Timber • Fuelwood • Drinking and irrigation water • Fodder • Nontimber products (vines, bamboos, leaves, etc.) • Food (honey, mushrooms, fruit, and other edible plants; game) • Genetic resources	• Remove air pollutants, emit oxygen • Cycle nutrients • Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) • Maintain biodiversity • Sequester atmospheric carbon • Moderate weather extremes and impacts • Generate soil • Provide employment • Provide human and wildlife habitat • Contribute aesthetic beauty and provide recreation
	• Drinking and irrigation water • Fish • Hydroelectricity • Genetic resources	• Buffer water flow (control timing and volume) • Dilute and carry away wastes • Cycle nutrients • Maintain biodiversity • Provide aquatic habitat • Provide transportation corridor • Provide employment • Contribute aesthetic beauty and provide recreation
	• Livestock (food,	• Maintain array of watershed functions (infiltration, purification,

	game, hides, fibre) • Drinking and irrigation water • Genetic resources	flow control, soil stabilization) • Cycle nutrients • Remove air pollutants, emit oxygen • Maintain biodiversity • Generate soil • Sequester atmospheric carbon • Provide human and wildlife habitat • Provide employment • Contribute aesthetic beauty and provide recreation

10.4 CAUSES OF BIODIVERSITY LOSS

Asia's biodiversity is being gradually lost. While it is not possible to quantify rates of species loss very precisely. However, high rates of land, fresh water and marine habitat degradation in this region is a reflection of species loss. It is estimated that Asia will lose more than half of its remaining land and water habitats over the next few decades.

The main causes of biodiversity loss include land-use changes, changing levels of atmospheric carbon dioxide, changing climate, invasive species and nitrogen deposition (air pollution). The causes of biodiversity loss are many and varied, and often interrelated. You will study about these factors in detail in the following subsections.

10.4.1 Habitat Destruction

Habitat refers to the area where species seek food, get shelter, and reproduce. The greatest threat to wild plant and animal species is due to destruction or alteration of their habitat. If an animal's habitat is destroyed or disrupted, it must either adapt to the new changes, move elsewhere or die. When it is forced out of its territory, and if it finds a suitable habitat there is a possibility that the habitat is already in use. Consequently, it must compete with the local population of the same species as well as other animals. The other option is that it must migrate into a marginal habitat where it may succumb to predation, starvation or disease. Some organisms such as pigeon, house sparrow, rodents (like rat and mice) and deer flourish in the modified habitats provided by human activities but many others do not.

Some habitats are more vulnerable to species extinction, these are called fragile habitats. **Coral reefs, oceanic islands and mountain tops are important fragile habitats.**

Box 10.1: ***Fragile habitats***

Coral Reefs

Coral reefs have been found to be particularly fragile as they are susceptible to a rise in water temperature, sea levels and the introduction of pollutants and sediments that changes water quality. Coral reef development is greatest in warm, shallow sun drenched areas and it needs clean, clear water. Productivity is decreased, or even eliminated, in areas subject to dirty sediment-laden water. Coral growth is naturally very slow.

In 1992, about 10% of the earth's existing coral reefs were found to be irreparably damaged, while 30% were expected to suffer damage within the next 20 years. It is also expected that there may be a further 30% loss within the next 20-40 years if remedial action is not implemented. It is estimated that Tsumani, 2004 has completely destroyed the coral reefs of coastal areas of India, Srilanka and Thailand.

Oceanic Islands

Existing data shows that 75% of the recorded animal extinctions since 1600 have been on islands rather than in continental areas, and terrestrial species in isolated oceanic islands are more vulnerable to being wiped out than continental species. The reasons for species extinction on oceanic island are restricted ranges, threat from alien species and characteristics of island species.

Habitat Islands

Species in ecological islands or "habitat islands" (areas of habitat separated from other such areas by inhospitable environments that act as effective barriers to dispersal) are at greater risk of extinction. For instance, freshwater lakes – bodies of water surrounded by land – like real islands, suffer high rates of extinction due to habitat modification or the introduction of exotic invasive species. Among continental extinctions, at least 66% of species loss has been in aquatic habitats.

Biodiversity loss in lakes is further increased by the fact that isolated inland water bodies can also have a high species endemism, resulting in global extinctions when these species are lost.

Most species need undisturbed habitat – unpolluted living space to find food and nutrients, water, shelter and mates. But people are altering habitats all over the world through following activities. This factor is recognised today as the most significant threat to global biodiversity and bears responsibility for much of the species loss worldwide. This includes:

- felling of forests for land use (i.e. clear felling for development, agriculture, etc.), large scale logging and small scale patchwork agriculture. Shifting cultivation alone is believed to be responsible for 70% of deforestation in Africa, 50% of deforestation in Asia, and 35% of forest loss in the Americas.
- destruction of mangrove sites for aquaculture
- mining and destruction of corals
- conversion of wetlands for land uses
- over-extraction of timber and fuel wood
- human-induced firing of habitats (e.g. forest firing for shifting cultivation and firing grasslands to improve fodder for cattle)
- damming of rivers
- siltation and sedimentation of freshwater bodies
- pollution also disturbs the natural habitat considerably. Industrial wastes cause severe impact, particularly on the aquatic habitats. For example,

although the impact of acid rain is far from being understood, it may be a slow, subtle agent that is driving some species in the lakes and streams to extinction. Furthermore, during the 1950s and 1960s, insecticides particularly chlorinated hydrocarbons (such as DDT), reduced the population levels of several birds such as the bald eagle, brown pelican considerably.

Habitat loss is not only important in that it results in species loss, it also represents biodiversity loss in its own right. In many countries there are very few pristine areas that have not been modified in some way by humans. For example, Bangladesh has only about 6% of its original vegetation left now. In Sri Lanka too, much of the dry zone forests are secondary as they had been cleared for cultivation many centuries ago. Of the wet zone forests, only a few like parts of the Sinharaja forest remain as virgin forests; many of the others have been selectively logged for timber in the past decades.

When habitats are not completely destroyed, they are fragmented into smaller patches, creating islands of habitat in a sea of development. Fragmentation exposes species to more light, wind and temperature effects than are natural, thus affecting the species survival as food and water sources are lost and few mates remain. In fragmented landscapes many species soon become isolated from others of their own kind resulting in inbreeding, loss of genetic diversity and local extinction.

Box 10.2: Coastal fauna destruction by Tsunami, 2004

The tsunamis which rose out of the Indian Ocean on 26th December 2004, triggered by a massive earthquake near the Indonesia island of Sumatra have caused devastation in coastal areas of India, Thailand and Srilanka. The Ocean's seagrass bed and mangrove ecosystem has been effected but it is the coral reefs that bore the brunt of the destruction. The coral reef system might be totally destroyed. It will take hundreds of years to grow back. When a tsunami passes, reef structures grind into each other causing extensive damage. In serious cases, recovery would be slow as there would be fewer larval animals to repopulate the coral. A major problem would be a loss of fish displaced by the waves from their habitat and other forms of protein which depend on the reefs. Large stretches of oyster beds and coral reefs across the southern Indian coast have been completely washed away by the killer tsunami, which caused large scale destruction of massive life and scientists believed that it would take a long time for the precious ecosystem to restore. The after effects would be equally devastating on the reefs, which are spawning, breeding and nesting grounds for thousands of marine animals, have been almost wiped off the aquatic map of the Indian Ocean

We shall now take up the issue of habitat destruction due to deforestation, and elaborate on it further. More than three quarters of the species that are in danger of extinction today are due to the destruction of their forest habitats. A large number of these species are from the tropics, where human population growth has been most explosive and habitats have been destroyed most rapidly. Tropical rain forests cover a mere 7 percent of the earth's surface, yet they house about three quarters of the total species. Today these forests are being destroyed at an alarming rate, and if the ecosystems are obliterated, hundreds of thousands of species will be lost forever, and some of these may be of great importance. We shall now tell you about a species of wild corn, which got accidentally saved. Several years ago, a hillside in Mexico was being ploughed when a few alert scientists discovered a previously unknown species of wild corn – *Zea diploperennis*, that only grew on that hill and was found nowhere else. These corn plants are perennial whereas the domestic varieties of corn are annuals. Moreover, the wild corn is resistant to many diseases that infest domestic varieties. The species was thus saved and it is now being used to breed and improve new domestic varieties. So it is of utmost importance to save the living species from extinction from the face of the earth.

The Great Indian Bustard has been exterminated because of habitat destruction and hunting. Similarly, the Bengal tiger faces extinction as its jungles are torn down to supply timber and farm land.

10.4.2 Over Exploitation of Resources

People use some plant and animal species at a greater rate than the species can replace themselves, which can lead to extinction. Nine of the world's major ocean fisheries are declining because of too much fishing as well as water pollution and habitat destruction. Popular commercial species such as the southern bluefin tuna, the Atlantic halibut and the Pacific and Atlantic salmon are now threatened. Current logging rates threaten to eliminate mahogany and other tree species that take many years to grow and mature.

The $10 billion-a-year global market in wildlife – for pets, folk medicines, gourmet foods, decorative objects and other uses – threatens elephants and rhinos, sea horses and colourful corals, tropical plants and birds, and bears, pandas and tigers.

Over harvesting of resources includes:

- **Poor land use planning** including ad hoc agricultural expansion and siting of development schemes, hydro-power projects, human settlements and mining projects.
- **Selective removal of economically important organisms** or their parts, such as over-harvesting of non-timber forest resources, edible species, ornamental fish and plants, and species of medicinal/medical use.
- **Replacement of indigenous varieties of crop species with new hybrids** that are higher yielding but are less resistant to pests, local conditions and need more fertilizer.
- **Hunting** for sport or subsistence, live capture for commercial use and deliberate extermination of species as pests.

10.4.3 Hunting and Export

The hunting and export of excessive numbers of certain animal species is another important factor leading to dangerous reductions in numbers. There are three main types of hunting:

i) **Commercial hunting** – in which the animals are killed for profit from sale of their furs or other parts;

ii) **Subsistence hunting** – the killing of animals to provide enough food for survival; and

iii) **Sport hunting** – the killing of animals for recreation. Although subsistence hunting was once a major cause of extinction of some species, it has now declined sharply in most areas. Sport hunting is now closely regulated in most countries; game species are endangered only when protective regulation does not exist or are not enforced.

On a worldwide basis, commercial hunting threatens a number of large animal species. The jaguar, tiger, snow leopard, and cheetah are hunted for their skins, elephants for their ivory tusks (accounting for the slaughter of about 90,000 elephants a year) and rhinoceros for their horns. Single rhino horn – which is a mass of compact hair – is worth as much as $24,000 in the black market. It is used to make handles for ornamental knives in North Yemen, and ground into a powder and used in parts of Asia for medicinal purposes, especially reducing fever. It is also thought to be an aphrodisiac or sexual stimulant even though it consists of a substance (Keratin) that can be obtained by eating hair trimmings and finger nails. Although 60 countries have agreed not to import or export rhino horns, illegal trafficking goes on because of its high market value. The number of black rhinos in Africa dropped from 65,000 to about 5,000 between the years 1970 and 1986. And about 100 white rhinos were left by 1986. If poaching continues at present rates, all species of rhino will be extinct within a decade.

Another highly published commercial hunt is that of the whale. The whaling industry has generally concentrated its efforts on the large, profitable baleen whales, which were slaughtered for their blubber and baleen, the bony sieves they filter sea water with. From the blubber, a high grade oil was made for lamps and for lubricating machines. The baleen or “whalebone” was used to make corset stays, combs and similar products.

The history of whaling is one of over-exploitation followed by abandonment. Whales harvested a species until it approached extinction and then moved on to another profitable one, repeating the patterns many times.

The blue whale, the largest animal that has ever lived, once numbered around 2,00,000 but by the mid 1950s it has been reduced to about 1,000. Many scientists believe that the blue whale population, although now protected, may not recover.

10.4.4 Selective Destruction

The selective destruction of one species of an existing fauna can produce equally unfortunate results. The perfect demonstration of unexpected consequences of such destruction occurred in the early years of this century in the USA. In a mistaken effort to increase the deer herds on the Kaibab Plateau, President Theodore Roosevelt, himself a very keen naturalist, authorized the destruction of the natural enemies of the deer, the puma and the wolf. The result was not as expected. Deprived of their natural enemies, which had served to keep their number in check, the deers multiplied so rapidly that there was soon insufficient grazing areas to support them. As a result what had been fertile grassland capable of supporting large herds of deer was soon reduced to unproductive desert virtually unable to support any wildlife. As their available food supplied diminished so the deers died of starvation in the thousands, and in a very short time the total deer population fell far below what it had been when they were subjected to the full effects of their natural enemies.

Extinction or near extinction can also occur because of attempts to exterminate pest and predator species that compete with people and livestock for food. The Carolina parakeet was exterminated in the United States around 1914 because it fed on fruit crops. Its disappearance was hastened by the fact that when one member of a flock was shot, the rest of the birds hovered over its body, making themselves easy targets.

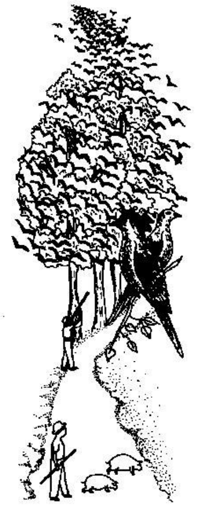

Fig. 10.5: Passenger pigeon a lesson learnt but too late.

When we talk of selective destruction we must narrate you the story of Passenger pigeon (Fig. 10.5). The Passenger pigeon (*Ectopistes migratorius*) probably was the most numerous bird on earth as recently as the middle of the nineteenth century. Passenger pigeons certainly were the most abundant birds in pristine North America. The records include very interesting details about these birds. They were in such immense numbers that their flocks darkened the sky during migration, and one such flock alone was 400 km long and had no less than two billion birds! So huge was their numbers that the branches of trees would break under the weight of the perching birds. It took hours for the flocks to pass through a place. There used to be as many as 90 nests per tree throughout a stretch of forest of about 5 km width and 67 km length. In 1871, an estimated 136 million passenger pigeons nested in a 2,200 sq. km areas of central Wisconsin. An immense tonnage of droppings fertilised the forests where passenger pigeons roosted. One interesting feature about these organisms is that a passenger pigeon laid just a single egg. All the above information gives us a picture of immense abundance of the species. But as you will see in the following details, an immense abundance does not exclude a species from extinction. Despite their large numbers, today there is not even a single passenger pigeon on the earth. You must be wondering why this extinction occurred. We shall discuss that now. Millions of passenger pigeons were killed for food.

In a span of three months in 1878, more than 1.5 million pigeons were shipped to market from a nesting area in Michigan. It is believed that, as many as 10 million may have perished due to hunting in the above area. The birds were served in fashionable restaurants in Chicago, New York and Boston for two cents each. Not sometimes were felled to obtain large numbers of young birds. Thus the outright killing of passenger pigeons often was accompanied by the destruction of irreplaceable nesting habitats. The lack of refrigeration meant that even more birds were killed to cover losses from spoilage during transportation to market. Another interesting aspect that played a great role in their extinction was the two technological developments – rail roads and telegraph, in the nineteenth century. The extensive rail network helped the pigeon hunters in providing ready access to the major nesting colonies of passenger pigeons east of Mississipi river. One dealer in New York received 18,000 birds a day as a result of the new rail connections. Because these birds were nomadic, the telegraph kept hunters informed about the locations of nesting colonies. Because the rail roads benefited from their association with the market hunters, the train companies also provided up-to-date information concerning places where pigeons might be caught. Such relentless disturbances of colonies resulted in large-scale nesting failures year after year, and passenger pigeons steadily diminished. The last pigeon – Martha died in Cincinnati Zoo in 1914, and its body is preserved and kept in U.S. Natural Museum in Washington. The decline and eventual extinction of such an abundant species now seems beyond imagination – but is an event marking one of the darkest hours in environmental history.

10.4.5 Pollution

The more we consume, the more we generate waste and pollution, which threatens biodiversity and our own health. Pollution comes in many forms – oil spills, acid precipitation, toxic chemicals in fertilizers and pesticides, and urban and suburban sewage runoff, to name a few. Pollution may kill organisms outright or it may weaken them by interfering with vital processes such as mobility and reproduction. Pesticides harm wild insect pollinators, including managed honeybee populations, which can in turn reduce crop yields. Runoff seeping into rivers, lakes and coastal environments can produce negative impacts on entire aquatic ecosystems.

Some 140,000 people become sick because of pesticides and pesticide runoff each year. Several pesticides banned in the United States are still exported to developing countries. Of particular concern are chemicals called endocrine disrupters such as DDT, DDE and PCBs. These substances mimic or interface with normal hormones in living organisms. Reproductive abnormalities have been found in alligators, terns, salmon and gulls exposed to high levels of chemicals from pesticides and animal hormones in their environment.

10.4.6 Pesticides

Another recently realised danger to wildlife in many parts of the world has come from the development of more effective pesticides. As agriculture became more efficient so the need to control crop pests also became more urgent, and the agricultural chemists have devoted a great deal of their time and energy to synthesise compounds to meet this need. In the early 1960s it became clear that a certain group of chlorinated hydrocarbons, notably aldrin, dieldrin and heptachlor, which are undoubtedly extremely effective in controlling pests, are proving increasingly harmful to many wild animals. Their great disadvantage, it was discovered, was that whereas most other pesticides were fairly rapidly destroyed when they fell on the ground, the above three pesticides persisted in the soil for years, and tended to accumulate (bioaccumulation) since each year's spraying reinforced the persisting residues from previous years.

The first effect of these pesticides is a gradual accumulation in the bodies of worms, insects and some small animals. These in turn are eaten by birds, which thus acquire these accumulations, and the effects of which may be reproductive failure and egg shell thinning. These effects have been seen in birds like peregrine falcon, eastern and California brown pelicans, osprey, bald eagle.

In India, the threat to wildlife through the use of these compounds had taken rather a different turn. Here the farmers have been using them directly as poisons to kill tigers, leopards and other large animals either by adding a few grams to the animal's food or by scattering poisoned bait along their known tracks. In Kerala, elephants have also been killed by poisoned bananas.

10.4.7 Global Climate Change

Substantial evidence demonstrates that people are contributing to measurable changes in the global climate, threatening life as we know it. By burning fossil fuels such as oil, natural gas and coal and by burning trees to clear forests, we have dramatically increased the amount of CO_2 in the atmosphere. While scientists do not know the exact effects of increased CO_2, they predict that it will lead to higher overall global temperatures, increasing sea levels, and changes in climate patterns.

The changed atmospheric conditions that result from global warming could create greater numbers of intense storms and prolonged droughts. The warming may lead certain species to expand their ranges, including mosquitoes that carry malaria and encephalitis among other diseases. On the other hand, the expected speed of climate changes coupled with direct loss of natural habitat may prevent some species from adapting quickly enough. They are likely to become extinct, locally or more broadly, and their roles in natural systems will be lost forever.

Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. Corals are "bleaching" (losing their necessary symbiotic algae) throughout the world because of increased water temperatures, and many are not recovering. The goods and services lost as ecosystems are fragmented or disappear, including changes to and loss of biodiversity, are likely to be very costly or impossible to replace.

10.4.8 Invasive Species

Purposely or accidentally, people often bring non-native species into new areas where the species have few or no natural predators to keep their populations in check. These invasive species – also called **alien**, **introduced** or **exotic species** – are considered the most important cause of biodiversity loss. Invasive alien species which are accidentally or intentionally introduced into new areas. They range from microbes to mammals. Invasive species also cause economic and environmental havoc. Invasive species can also alter fire cycles, nutrient cycling and the hydrology and energy budgets in native ecosystems. The problem of invasive species will rise severely through climate change. According to Dr. Mac Kinnon, alien species have been introduced to a country by people with good motives in mind, but may lead to disastrous results.

As long as human beings have travelled around the world, they have carried with them (accidentally or intentionally) many species of plants and animals, which they have introduced to new geographical areas. In some instances, an opening has existed in the new environment and the foreign or alien species has been able to establish itself without seriously affecting the population size of the native species. But in other instances, the alien has been a superior predater, parasite or competitor, and has brought about extinction or near

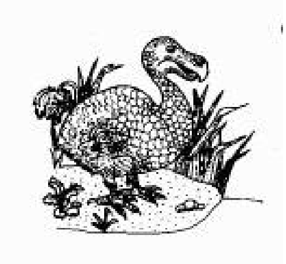

Fig. 10.6: Dodo, the first animal species whose extermination could be fully documented.

extinction of native species. It can also cause a population explosion of the existing species by killing off their natural predators. Island species are particularly vulnerable because many have evolved in ecosystems with few if any natural herbivores, or carnivore predators.

In 1859 a farmer in southern Australia imported a dozen pairs of wild European rabbits as a game animal. Within six years these 24 rabbits had mushroomed to 22 million so that by 1907 they had reached every corner of the country. By the 1930s, their population had reached an estimated 750 million. They competed with sheep for grass and this cut the sheep population to half. They also devoured food crops, gnawed young trees, fouled water holes and accelerated soil erosion in many places. In the early 1950s, about 90% of the rabbit population was killed by the deliberate human introduction of a virus disease. There is a concern, however, that members of the remaining population may eventually develop immunity to this viral disease through natural selection and again become the scourge of Australian farmers.

We shall now take up another example that demonstrates the devastating effects of the introduction of alien species on islands. In islands, particularly the endemic species are often inadequately equipped to deal with invasions of humans and their domestic animals. For example, the bird dodo (Fig. 10.6) lived only in Mauritius, which is a small island. The dodo possessed two characteristics that were its eventual undoing; it had no fear of people and, therefore, could be easily clubbed to death, and it was flightless, so, it had to lay its eggs on the ground. The dodo became extinct by 1681, after the introduction of pigs to the island, who devoured its eggs. The extinction of Dodo may also be analysed in terms of changed habitat conditions due to the introduction of a new species – pigs, to the island.

On an island, both the variety of habitats, and the area that comprises each habitat are physically limited. As a result of such constraints, the native animals' ability to adapt to new predators and competitors is often reduced. For example, the habitat may not be large enough or diverse enough for a prey species to avoid new predators. And the diversity of resources may not be adequate to allow an existing species to coexist with a new competitive species. Hence, in some instance competitive exclusion leads to extinction of the native species. For example, the habitat was not large enough or diverse for the prey species (Dodo) to avoid new predators (pigs).

Competition exclusion can be illustrated by the demise of tortoise on one of the Galapagos islands after fisherman released some goats on the island in 1957. When a research team from the Charles Darwin Station arrived in 1962 to investigate the tortoise population on the island, they found only empty tortoise shells, many of which were wedged among the rocks that covered the upland slopes. Investigations of the lowland indicated that all the vegetation that had previously been within reach of the tortoises had been consumed by the flourishing goat herd. As a result, the hungry tortoises apparently were forced to obtain food on rocky slopes, where they subsequently either became entrapped between rocks or fell over precipices and starved to death.

Island flora, too, has been devastated by the introduction of alien species. For example, in the Hawaiian islands, no large herbivorous animals existed until the 1700s, when Europeans introduced domestic livestock. Because no prior selection pressure had existed to favour them, thorns or poisons to ward off herbivores were not characteristic of native plants. Moreover, the limited size of habitats on the islands favoured overgrazing. Thus species that had not been threatened previously were devastated by grazing animals. As a result, nearly one half of the native vegetation in the Hawiian islands is thought to be in danger of extinction.

An island, in the usual sense of the word, is a land mass that is surrounded by water. Ecologically, however, a *habitat island* is defined as any restricted area of habitat that is surrounded by dissimilar habitats. Hence, a lake without outflow is considered to be an aquatic island. Also, when natural habitats are bisected by highways and converted into farms and cities, natural and semi-natural areas become increasingly smaller and more isolated (Fig. 10.7). To save what little remains, some of those isolated areas have been set aside as parks and conservancies. Forest preserves are usually widely scattered and the intervening highways, farms and cities serve as barriers that prevent the migration of many species of plants and animals into and out of them. Hence those natural and semi-natural habitats have become islands as well, and the animals and plants that live in them are subject to the same pressures as those living on islands that are surrounded by water. Furthermore, the smaller the habitat island, the greater is the pressure on its inhabitants. Thus we would consider these factors when we plan how to use land rather than indiscriminately invade and carve up natural habitats into increasingly smaller pieces.

Some other classic examples are:

- Golden apple snail is one of the most devastating invasive alien species. It was imported from Latin America to South East Asia in the 1980s.
- Water hyacinth, a water plant with a showy purple flower was a native of the Amazon Basin and is now seen as the most important nuisance aquatic plant worldwide. It affects water flow, electricity generation, transport, water quality and indigenous biodiversity.
- Prosopis (Mesquite) in the Thar desert of India has displaced other flora of the area, while the species introduced to a semi-arid area of Sri Lanka in the early 1950s, has become as invasive seriously threatening the biodiversity of the only Ransar– listed wetland of the country.

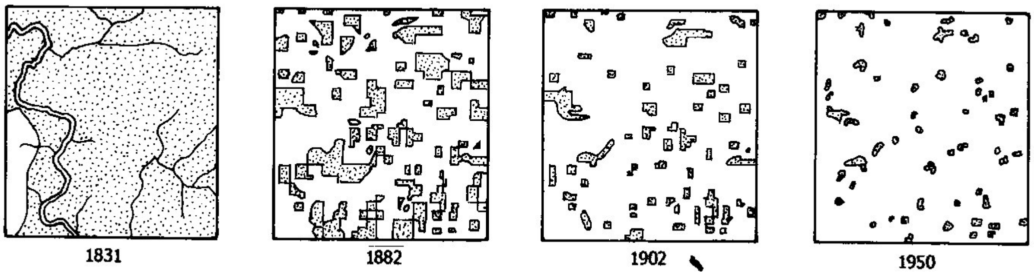

Fig. 10.7: The reduction and fragmentation of woodland (shaded areas) in Cadiz township, Wisconsin between 1831 and 1950. The piecemeal destruction of habitat resulted in piecemeal extinction of many species (after J. Curtis, 1955)

10.4.9 Domestication

It means that man has taken under his direct care the living beings which are useful to him. Through extensive breeding programmes, he has modified them to derive maximum benefit of their products. During the process, the species have lost certain useful characteristics so much so that these forms cannot survive on their own in nature. A very good example is corn, which is pampered so much by man that if it is left on its own, it cannot survive.

We shall now take up the other aspect of how domesticated species create hostile conditions for the survival of wildlife.

Today man has large herds of domestic animals. These animals can also play a significant part in the reduction of animal populations by overgrazing the land, thus destroying the vegetation on which both they and the wild animals depend. The native wildlife of a particular area is capable of utilising the native plant life much more efficiently than introduced domestic cattle, and is thus much less likely to convert fertile areas into deserts. So, often domestic animals have little more than prestige, value, providing little in the way of either meat or milk.

The other important parameter is that the domestic cattle are carriers of several diseases which they can transmit to wild animals. For example, the steady rehabilitation of the Great Indian Rhinoceros was seriously hampered by the rinderpest disease which they contracted from the local domestic cattle.

Carolina parakeet–their brightly coloured leathers caused their downfall. These feathers were prized for decorating women's hats and made the birds popular as pets. Their extinction came in 1914. The heath hen was used as food. In the early 1900s people realised that the bird was becoming scarce and a bird sanctuary was set up. The flock soon grew, but a fire swept across the sanctuary, and only a few males survived. The last bird died in 1932.

The Labrador duck became extinct before anyone realised it was gone. Most of the birds were killed for their feathers, which were used to stuff pillows.

Among all the countries, India has the greatest number of mammalian species on the threatened species (endangered, rare etc.) list, and in the Red Data Book, ranks first of the world.

SAQ 3

a) Oceanic islands are particularly vulnerable to species extinction because

   i) Species in them have restricted ranges

   ii) Species in them are not adapted to compete with introduced alien species

   iii) Many species in them have characterises that make them vulnerable to predators

   iv) All of the above

b) Habitat islands are best described as:

   i) Lands surrounded by water

   ii) Habitats surrounded by environments inhospitable to species that they contain

   iii) Fragile habitats of high risk to species extinction

   iv) All of the above

c) The main reason for animal species extinction at the current high rates are:

   i) Habitat destruction

   ii) Hunting

iii) Over harvesting from the wilds

iv) Competition from alien invasive species

d) There is depletion of crop genetic diversity due to

i) Replacement of indigenous varieties of crop species with new hybrids

ii) Expansion of monoculture

iii) Selective breeding of some varieties of crops

iv) All of the above

10.5 MAJOR IMPACTS OF BIODIVERSITY LOSS

The continued loss of biodiversity will greatly impact human society as well as ecosystem and their valuable services. It is difficult to quantify these impacts. But looking at all the products and services biodiversity provides – and the difficulty of their replacement - gives us an idea of the magnitude of the consequences we face if we do not conserve the biodiversity.

There are several perceptible effects of biodiversity loss at both global and national levels. Some major effects are listed as follows:

i) **A steady increase in atmospheric CO_2 level** due to disruption of the carbon cycle in nature, is one of the most obvious of global climate changes in recent years. Clearing and destruction of tropical moist forest is expected to increase the atmospheric CO_2 and decrease the carbon-fixing potential of the biosphere.

> "Rises in temperature associated with *El Nino* and global warming have caused 180 coral bleaching episodes in the past nine years: this compares to 100 events in the preceding decade and only three recorded events in the previous century. These episodes have killed 95 percent of all shallow-water corals in the Indian Ocean."
>
> **Source:** MacKinnon, (2002).

ii) **Adverse effects on local climate and water flow** due to loss of tropical forests.

iii) **Decrease of overall population size of species** and loss of geographic range due to:

- splitting of previously contiguous (i.e. connected) populations into small isolated sub-populations that are more vulnerable to extinction than large populations. This occurs due to habitat fragmentation.

> A study of forest patches in the Brazilian Amazon has shown that forest fragments had lower species richness, a greater proportion of rare species, and less dense populations of species when compared with large undisturbed forest areas. The differences were greatest when the fragments were less than 1 ha.

  - their original habitat being made unsuitable for continued existence due to habitat modification by activities such as clearing, pollution and landfills.
  - contamination of soil and ground water by heavy metals and persistent organic compounds that make them unusable for agriculture; pollutants, pesticides and sediment added to soil and water that make habitats unusable to aquatic and soil living species, kills beneficial species and disrupts food webs.
  - the filling of wetlands by considering them as waste lands. This also serves to decrease the water holding capacity of these areas and results in the increase of propensity for flooding.
  - atmospheric pollution resulting in acid rain which kills trees and aquatic life, pollutes water, acidifies the soil, and damages buildings and materials: photochemical oxidants which harm crops and natural vegetation.

iv) **Extinction of species** which is the irreversible loss of biodiversity. The majority of the world's species, especially tropical invertebrates, have not been scientifically named or identified. When species are lost, we lose:

  - essential components of biodiversity needed to maintain the earth's life support systems. This reduces the ability of the biosphere to support human life.
  - crucial biological resources that are, or will be, economically, medically or agriculturally important to us are lost forever.

v) **Increased coastal erosion and loss of fishery productivity** as a result of the loss or degradation of coastal areas such as mangrove habitats and coral reefs.

vi) **Reduction of genetic diversity of crop species** due to replacement of traditional crop varieties and livestock by the use of high yielding, but less resistant and genetically uniform, varieties/species. This also results in the loss of traditional varieties that have evolved during centuries of domestication, and may have high resistance to adverse environmental conditions, disease and pests. This can have adverse implications on national food supply by decreasing the productivity of local agricultural systems and the sustainability of locally-adapted agricultural practices.

vii) **Loss of traditional knowledge and cultural practices** associated with the cultivation of traditional varieties that are lost.

viii) **Loss of livelihoods a** large proportion of the people in the world depends on bio-resources for subsistence use or their livelihood. This is seriously jeopardised due to loss of biodiversity.

There is no way, of course, to estimate losses of psychological, emotional and spiritual well being that will result from ruined forests, beaches, lakes and other places people rely on for rejuvenation.

SAQ 4

Which one of the following *does not* figure as a major impact of biodiversity loss:

a) Extinction of species

b) Reduction of crop genetic diversity

c) Decrease in population size of species

d) Increase in monoculture

10.6 BIODIVERSITY AND ECONOMICS

With the survival and well-being of human beings so heavily dependent on biodiversity, its economic value assumes considerable importance. For instance the economic value of ecosystem services and components of biodiversity is estimated at around US $ 33 billion, which is about 1.8 times more than the world's GNP. Another example is the pharmaceutical industry which still depends largely on wild bio resources; in India alone around 660 wild species are involved in all-India trade. Throughout the world, tourism based on appreciation of nature is growing, and it constitutes a major income earner for many countries of Asia.

Economic valuation should also show the economic costs associated with the loss or degradation of biodiversity and its components. This will include on and off-site loss of subsistence, loss or decrease of employment, loss of income and foreign exchange earnings and the cost of replacing or mitigating the loss of bio resources and ecosystem functions. For example

- Agriculture, forestry and fisheries account for 26 percent of total GDP and 70 percent of total employment in Vietnam. Despite the significance of this, improper use of natural resources and management patterns threaten Vietnam's continued economic viability.
- The 1997-98 Indonesian forest fires cost the country around US $ 10 billion due to the impact of transportation breakdown, loss of crops and timber, decline in tourism, health care, and others.
- Ecosystem degradation costs Australia about US $ 500 billion annually because of reduced production and nutrient loss.

  In South Asia the losses due to land degradation and desertification are US $ 10 billion, and about US $ 700 million in North East Asia according to Economic and Social Commission for Asia and the Pacific (ESCAP) reports.

However, according to conventional principles of economic analysis it is necessary that a resource is used for it to acquire a value. **Consequently economists traditionally value biological resources in terms of their direct uses, the raw materials they supply for human production and consumption.** For example, a living tree can only be valued in terms of the price it would fetch in the market place as timber; natural forest will be valued based on timber value; coastal and marine ecosystems are valued in terms of fisheries. This disregards all those vital services and functions of biodiversity that are not directly seen or perceived. Consequently they are taken for granted although irreplaceable and vital to sustain local economies.

Species and genetic material have long been exchanged in Asian markets (e.g. rice, timber and fish, utensils, cloth, etc) but there has been failure to give a value for the services provided by natural systems which therefore remain “worthless” in market terms. For example, the disruption in natural water regulation due to forest loss in the central highlands of Vietnam accounts for around 50 percent of seasonal fluctuations in rice production. It is important to recognize the vital importance of biodiversity services for local/national economy apart from sustaining life support systems.

Thus new approaches to economic assessment are required to ensure that economic values incorporate both monetary and non-monetary expressions of biodiversity value. Accordingly, a given habitat or species should have many different use and non-use values. For instance a rain forest may have values through contribution to watershed protection, carbon storage and soil conservation as well as values due to ecotourism, timber extraction, optional use and existence values based on ethical and/or aesthetic values. Many countries (particularly islands) in South Asia have long coastlines which combined with a tropical climate provide a multitude of coastal and offshore marine ecosystems such as estuaries, coral reefs, mangroves, sea grass beds, sandy beaches, rocky beaches and lagoons. Mangroves and coral reefs play a critical role by protecting the shore during hurricanes and storms.

10.6.1 Valuation of Biodiversity

Serious research in this field has only been recently initiated and the methodologies for valuation are still evolving. Important valuation work is being carried out in various pilot projects and monetary values are being given to biodiversity services. Practical tools are needed, however, to bring biodiversity into the economy – especially in the countries of South Asia. Part of the problem in valuation of biodiversity is that biodiversity services are often almost invisible and the loss or disruption of services are difficult to identify. Due to the resilience of nature, the loss of production with market implications of a magnitude that will awaken a political response may also become apparent only when the natural system is near total collapse.

A growing literature in applied economics is demonstrating that techniques are available for obtaining concrete estimates of the value of many different facets of the environment. This includes the more **intangible** (i.e. not directly observed) aspects of environmental quality, such as clean water, clean air and better scenic views. These methods can be applied to biodiversity, but are subject to major limitations and problems of interpretation. One of the major difficulties is that these methods are based on the premise that value is determined by human willingness to pay. The range of human values are very broad and consequently difficult to measure. For example, many people place an ‘existence value’ on certain natural resources that they will never personally see or experience.

Valuation of biological resources includes the process of deriving a monetary value to the things that are not sold in the market. Examples are the value given to fuel wood gathered in the forest, water filtration provided in a wetland or biological resource that may supply new medicines in the future. Valuation is essential for a “social cost- benefit” analysis of biodiversity (i.e. analyzing the costs and benefits of maintaining biodiversity for a society), and is linked to **“environmental accounting”** which means the modification of national accounts to take into consideration the economic role of the environment. Many countries in the world are now attempting this. It is believed that over 25 countries have experimented with environmental accounting over the past 20 years and a few European countries have already set up physical accounting systems that are routinely complied and applied to economic and environmental policy making. Biodiversity valuation can contribute to constructing environmental accounts at the national level.

10.6.2 Future Directions in Biodiversity Valuation

The methods that can be used for valuing biodiversity are still evolving at the global level, but studies have been done on how biodiversity values can be incorporated into the process of decision making for investment projects. In carrying out valuation studies, it is necessary to emphasize the importance of adopting appropriate criteria and methods and focusing on values that are of relevance to the respective countries. In this regard, however, we need to be able to see the distinction between valuing only individual biological resources and valuing biological diversity (i.e. the existence of a range of variation in biological resources, whether measured quantitatively or qualitatively).

A balanced approach to understanding the values of biodiversity in the context of ecosystem services should be based on the understanding that people in all countries and regions depend daily on ecosystem services from terrestrial as well as aquatic habitats for managing their lives. This underscores the need to value and conserve the natural ecosystems of all countries and regions rather than only on biodiversity hot-spots or charismatic species. Identification and recognition of ecosystem services is therefore required at various scales from local to regional, national and global.

Overall, while it is evident that neither ethical nor aesthetic arguments alone provide sufficient grounds for attempting to maintain all the earth’s existing biological diversity. A more general and practical approach recognizes that different but equally valid values (resource values, optional values, ethical and aesthetic values, etc.) can assume importance in different cases, and together can provide an overwhelmingly powerful case for the conservation of the earth’s biodiversity.

In current practice, many of the arguments used to justify the conservation of biodiversity stress the benefits, both economic and otherwise, from the sustainable use of biological resources. However, the argument for biodiversity conservation on economic grounds alone is insufficient to ensure its long term preservation. It is a fact that aesthetic, moral or other values are just as valid and necessary as financial values to justify the conservation of biodiversity.

SAQ 5

What is environmental accounting?

10.7 SUMMARY

Let us summarize what you have learnt so far.

- Humans benefit from biodiversity in many ways. Besides the animals and plants that we use for food, shelter, raw materials, and companionship, there are thousands of species whose natural products are literally life saving.
- Biodiversity produces goods and services for our fundamental needs.
- Plants and animals are being consumed as food. Approximately 80,000 edible plants have been used in human history, although about 150 have ever been cultivated. Invertebrates e.g. insects (mainly termites), marine molluscs (oysters), arthropods (crabs, shrimps, lobsters) and vertebrates e.g. fish, food obtained from cattle, sheep, poultry are important edible food items.
- Plants and animals are sources for medicines and drugs. Approximately 30% of pharmaceuticals in market today are developed from plants and animals. Antibiotics are extracted from microorganisms. Biodiversity is source of medicines to combat diseases and pests that threaten human health, agriculture and animal husbandry.
- Biodiversity is source of industrial raw material. Silk industry and rattans industry are important examples.
- Biodiversity provides firewood, and other biomass for energy.
- Biodiversity is an important source for wood which is very useful in timber trade.
- Biodiversity provides services mainly in terms of ecosystems regulation.
- Ecosystem provides habitat for the world’s species.
- Pollination, air and water purification, climate regulation, drought and flood control and cycling of nutrients are important services provided by biodiversity.
- Spiritual and aesthetic senses of human beings pave a way for economic value of biodiversity.
- Biodiversity is threatened by the sum of all human activities. It is useful to group threats into the categories of habitat destruction, invasion of non-native species, over-hunting, pollution and climate charge.
- Habitat loss presents the single greatest threat to world biodiversity, and the magnitude of this threat can be approximated from species-area

curves and rates of habitat loss. The spread of non-native species threatens many local species with extinction, and pushes the world's biota towards a more homogeneous and widely distributed sub-set of survivors.

- Climate change threatens to force species and ecosystems to migrate toward higher latitudes, with no guarantee of suitable habitat or access routes.
- Habitats that are vulnerable to greater species extinction are referred to as fragile habitats. Coral reefs, oceanic islands, mountain tops and habitat islands are considered as fragile habitats.
- Major impacts of biodiversity loss are steady increase in atmospheric CO_2 level, adverse effects on local climate and water flow, reduction of genetic diversity, extinction of species and loss of livelihoods.
- Economic value of biodiversity is of paramount importance. Economic valuation reflects the interaction between loss/degradation of biodiversity and the economic costs. Economic valuation is an integral part of biodiversity assessment.
- Valuation is essential for a 'social-cost benefit' analysis of biodiversity and is linked to environmental accounting.
- Biodiversity valuation planning requires that the benefits provided by genes, species and ecosystems, and the costs of their loss and all forms of capital must be fully valued.

10.8 TERMINAL QUESTIONS

1. How does biodiversity help in ecosystem regulation?
2. "Recreation and tourism pave a way for economic value of biodiversity". Discuss this statement.
3. Discuss how invasive species and indiscriminate use of pesticides led to biodiversity loss.
4. Discuss the major impacts of loss of biodiversity.
5. How biodiversity valuation is significant in biodiversity conservation?
6. What important considerations should be undertaken in valuation of biodiversity?

10.9 ANSWERS

Self-Assessment Questions

1. a) A large number of important drugs are derived from plants. For example **Tubocuranin**, derived from plant-based curare, is used as a muscle relaxant during surgery.

b) ***Catharanthus roseus:*** This species yielded the alkaloids vincristine and vinblastine. Traditionally used by various cultures for the treatment of diabetes, these compounds were first discovered as part of an investigation of the plant as a possible oral hypoglycemic. Originally native to Madagascar, this species is now widespread and common. The vinca alkaloids are used in the treatment of childhood leukemia and Hodgkin's disease.

c) The wood from conifers (e.g. pine) is called **softwood** and the wood from broad-leaved trees (e.g. oak) is called **hardwood**. Most paper is made from softwood trees such as fir, pine and spruce. About 70% of the world's timber needs are met by softwoods derived from the coniferous trees.

2. By giving off moisture through their leaves and providing shade, plants help keep us and other animals cool. Forests are especially good climate modifiers. Forests act as insulators helping to mitigate the impacts of freezing temperatures. As trees and other plants in forests release oxygen and take up carbon dioxide (CO_2) – the most prevalent greenhouse gas – the forests store carbon and help reduce global warming. So do oceans as they interact with the atmosphere. Algae living in the ocean take up carbon dioxide, and ocean currents and winds help control the world's climate.

3. a) All of the above

   b) All of the above

   c) Habitat destruction

   d) All of the above

4. Increase in monoculture

5. Environmental accounting means the modification of national accounts to take into consideration the economic role of the environment.

Terminal Questions

1. Refer to Section 10.3.

2. Refer to Subsection 10.3.10.

3. Refer to Subsections 10.4.6 and 10.4.8.

4. Refer to Section 10.5.

5. Refer to Subsection 10.6.1.

6. Refer to Section 10.6.

Acknowledge

Table 10.4: 2000 World Resources 2000-2001:.People and ecosystem: The fraying web of UNDP, United National Environment Programme, World Bank, World Resources Institute.

UNIT 11

INTERNATIONAL CONVENTIONS ON BIODIVERSITY

Structure

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    Objectives
11.2 International Conventions on Biodiversity
    International Union for Conservation of Nature (IUCN)
    Millenium Development Goals in Biodiversity
    Convention on Biological Diversity
    Convention on International Trade of Endangered Species of Fauna and Flora (CITES)
    Ramsar Convention
    Bonn Convention
    The World Conservation Strategy (WCS)
    Cartagena Protocol on Biosafety (2000)
11.3 Biodiversity Conservation at National Level
    National Framework for Biodiversity Conservation
    Wildlife Protection Act
    Environment Protection Act (EPA), 1986
    Biodiversity Act 2002
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11.5 Terminal Questions
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THE PEOPLE'S
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11.1 INTRODUCTION

Biodiversity plays an essential role in the functioning and maintenance of ecosystems. Biodiversity has shown a drastic depletion in the last few decades. Overexploitation, loss of habitat, pollution, climate change, and the introduction of exotic and alien species have led to a huge amount of biodiversity loss. Rapid acceleration in loss of biodiversity has initiated an immediate need for its conservation. Several legal frameworks and laws have been formed and executed for the protection and conservation of flora and fauna at the global level. Legislation came into practice for the enaction and implementation of laws related to the prevention of destruction and damage of the natural resources and biodiversity. Legislation is important for ensuring the implementation of laws. Legislations implemented in the countries are called Acts, while those enacted throughout the world are called Conventions.

Some important environmental acts in the context of protecting biodiversity and conventions which are enacted to ensure biodiversity conservation have been discussed in this unit.

Objectives

After studying this unit, you should be able to:

- discuss various points that will highlight the value of biodiversity;
- emphasise the need for biodiversity protection; and
- describe various acts and conventions related to biodiversity conservation.

11.2 INTERNATIONAL CONVENTIONS ON BIODIVERSITY

Several international conventions were held in various areas of the globe to gather international attention and foster cooperation in safeguarding biological diversity. International legislation is related to the consent for a common cause among the participating countries (or parties). Global issues are discussed on one platform, policies are framed and treaties are signed. Legislations are agreements which are signed by the willing nations and strictly followed. Conventions or treaties are the global agreements which get finalised.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora, held in 1971, emphasised the need for protection/safeguarding of wild fauna species whose number has declined drastically due to illegal trade carried out for products such as skin, tusks, and bones. It also focused on the protection of important wild flora species that were being smuggled because of their immense value in the international market.

A conference focusing on the topic of ‘Environment issues/concerns and Development’ was organised at the United Nations in 1972. The meeting was held at a place called Stockholm, hence it was given the name Stockholm Conference. This was the first global initiative to address and focus on the issue of environmental degradation. An idea of creating an organisation such as the United Nations Environment Programme (UNEP) was conceptualised during the Stockholm conference. An organisation named the International Union for Conservation of Nature and Natural Resources (IUCN) (also known as the World Conservation Union) *w*as constituted in 1948 with the aim of making governmental and non-governmental organisations work together for the cause of safeguarding biodiversity and natural resources and promoting their sustainable use. About 81 countries of the world are its members. The headquarters is located at Gland, Switzerland.

The Stockholm Declaration of 1972 sets out 26 principles related to environmental protection along with life. The Declaration emphasised the need for safeguarding the environment and biodiversity. The second principle of this declaration states that "the natural resources that cover air, water, land, flora and fauna and natural ecosystems must be protected for the sustenance of present and future generations through suitable planning and management." According to Principle 4 of this declaration, “Man holds the duty to conserve and suitably maintain inheritance, including wildlife and its habitat, which are being destroyed due to many factors. Nature conservation, therefore, needs to be given priority during the planning of economic development." The World Commission on Environment and Development (also called the Brundtland Commission) proposed a law for biodiversity protection that emphasises the requirement of safeguarding biodiversity and the need for achieving the target of sustainable use of natural, animal and plant resources.

A convention for the prevention of marine pollution caused by land sources was held in 1974. The Convention on Long-Range Transboundary Air Pollution was held in 1979. Both the meetings emphasised the removal of pollution from the environment so as to protect biodiversity. The Bonn Convention (or Convention on Migratory Species), held in 1979, formulated an international agreement with the aim of conserving terrestrial, aquatic and migratory avian species. In 1980, the United Nations Environment Programme (UNEP), World Conservation Union (WCU), and World Wildlife Fund (WWF) prepared a strategy for the protection of the diversity of living organisms essential for the maintenance of ecosystem processes and the use of organisms in a justified manner. This formed the basis of an international agreement known as the World Conservation Strategy (WCS). A World Charter for Nature prepared by IUCN was implemented by the United Nations General Assembly on 28th October 1982. The Charter developed principles of conservation which guide all humans about their conduct that is affecting nature. The Charter states that "every form of life is unique and deserves respect, irrespective of its use to man." The Principle 2 given in the Charter states that "The genetic viability on the earth shall not be compromised; the population levels of all life forms, wild and domesticated, must be at least sufficient for their survival, and to this end necessary habitat shall be safeguarded.” Principle 10 of this charter emphasises regulating human activities that affect nature and stresses the use of the best available technologies to minimise risks.

Later, the Vienna Convention held in 1985 focused on the protection of the ozone layer. The Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal of 1989 was formulated to protect all biodiversity, including humans. The Earth Summit held in 1992 emphasised the need for other global treaties and initiatives related to biodiversity conservation.

11.2.1 International Union for Conservation of Nature (IUCN)

It is an international organisation formed in the year 1948. It is headquartered in Switzerland. It is a set of government and civil society organisations (CSOs). It is one of the world's largest environmental networks, with around 1300 subordinate organisations that work for the protection of nature and the natural world. The organisation works in many areas, including biodiversity conservation and sustainable development. It is a global authority which supports government and non-governmental organisations by providing knowledge and other services required for conservation of nature. It also ensures that nations progress and economic development is not hindered.

Functions and objectives of IUCN

- It supports conservation projects carried out throughout the world.
- It supports projects where the traditional knowledge of local communities can be used to restore ecosystems, prevent habitat loss, and improve the well-being of people.
- It works majorly in six areas focused on survival of species, establishment of protected areas, enforcement of environmental laws, social and economic policy, ecosystem management, education, communication and awareness.
- It started programmes and initiatives across the world. These mainly include the IUCN Red List of Threatened Species, IUCN: Nature 2030, etc.
- It also provides a system of classification of taxa based on worldwide status.
- More importantly, it provides a Red List of Threatened Species, which is the most comprehensive inventory of the global conservation status of plants, animals and other organisms.
- It evaluates and assesses the status of existence of species and subspecies existing all over the world.
- The red list provided by IUCN is shared with government agencies, wildlife departments, policymakers, planners, non-governmental organisations (NGOs), educational organisations, students, and the business community.

IUCN Red List

- According to the IUCN Red List, organisms can be listed under nine different categories (Fig. 11.1). These include Not Evaluated (NE), Extinct (EX). Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Extinct in the Wild (EW), Near Threatened *(NT),* Least Concern (LC) and Data Deficient (DD).

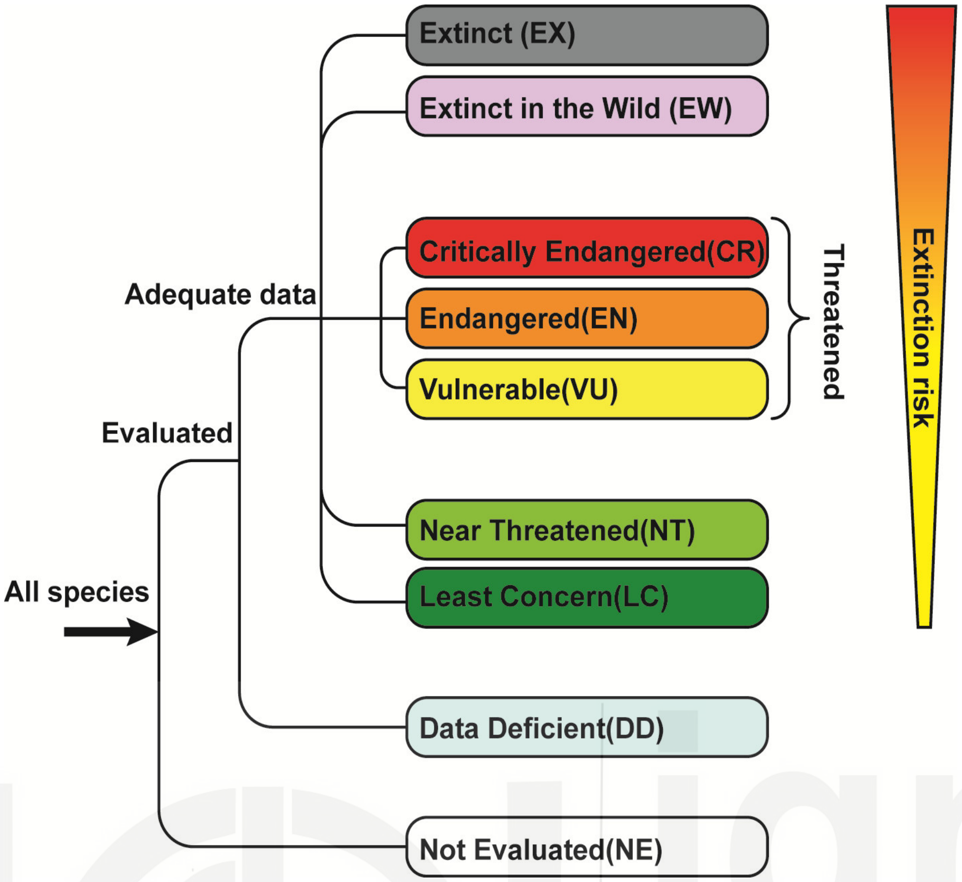

Extinct (EX)
Extinct in the Wild (EW)
Critically Endangered(CR)
Endangered(EN)
Vulnerable(VU)
Threatened
Extinction risk
Adequate data
Evaluated
Near Threatened(NT)
Least Concern(LC)
All species
Data Deficient(DD)
Not Evaluated(NE)

Fig. 11.1: Various categories listed in Red Data Book of IUCN.

Extinct (EX)

This category includes species of which no single individual is left or even the last individual has died.

Extinct in the Wild (EW)

This category includes those species whose wild members are extinct but a few survive only in cultivation, captivity or as a naturalised population (or populations). The individuals are present outside their range.

Critically Endangered (CR)

This category includes species that are at high risk of extinction, as 90% of the population has declined in the last ten years (or three generations), and at present, fewer than 50 individuals are left.

Endangered (EN)

This category includes species that possess a risk of extinction as a population decline of about 50 to 70% has been noted in the last ten years (or three generations) or the number of individuals of a population is less than 250.

Vulnerable (VU)

A category containing species that possess a very high risk of extinction as their population is declining rapidly and about 30 to 50% of the population has been lost over the last ten years (or three generations), or the population has less than 1000 individuals.

Near Threatened (NT)

This category includes species that are neither Critically Endangered, Endangered nor Vulnerable now but are likely to get threatened in the near future.

Least Concern (LC)

This includes species for which a good number/abundant organisms are available, and they do not qualify for criteria of being designated as Critically Endangered, Endangered, Vulnerable or Near Threatened.

Data Deficient (DD)

This category includes species for which data related to their risk of extinction is not available.

Not Evaluated (NE)

This category includes about 1.6 million species which have been described but have not been assessed by the International Union for Conservation of Nature.

11.2.2 Millenium Development Goals in Biodiversity

The United Nations Millennium Development Goals (MDGs) include eight goals set by 189 member countries in the Millennium Declaration of the year 2000. The meeting was held in New York (headquarters of the UN). The time frame given for the achievement of these goals was the year 2015. The main objectives of the goals were to:

- eliminate extreme poverty and hunger
- achieve global primary education.
- empower women and promote gender equality
- reduce child mortality
- promote maternal health
- fight malaria, HIV/AIDS, and other diseases
- promote environmental sustainability
- develop a universal partnership for development

The goals were implemented after the signing of the Millennium agreement in 2001. Though biodiversity protection and conservation were not the only priority motto of the agreement, they were given consideration and included under Goal 7. Goal 7 of the MDGs considers the threat of environmental degradation and its effects on living beings and the planet and therefore focuses on ensuring environmental sustainability. Since genetic, species, and ecosystem diversity are essential in supporting livelihoods. Moreover, biodiversity provides both direct and indirect benefits, including food security, health, nutrition, and income generation. Hence, its role in achieving the MDGs has been widely recognised.

This goal also supports forest management practices and focuses on sustainable harvesting and management of fuel wood and non-timber forests. It also encourages the adoption of innovative methods where biodiversity, particularly traditional herbs, is exploited as a source of medicine for the treatment of various ailments. It also supports research activities and awareness campaigns related to the use of therapeutic plants. It also promotes the integrity of ecosystems by supporting initiatives such as the management of land and water resources. It also aims at protection of biodiversity through an ecosystem approach for watershed management to ensure adequate water supply. The goals also emphasise the need for developing suitable management methodologies for addressing issues of ecosystem imbalance.

11.2.3 Convention on Biological Diversity

The idea for having a convention only for biodiversity was given in the Earth Summit. About 150 parties agreed with the principles and signed the agreement. The agreement got implemented on 29th December 1993. It offered financial support for protection of biodiversity, identification of priorities related to conservation, transfer of technology for protection of biodiversity and emphasised sustainable use of biodiversity. India signed the agreement in 1994. The convention was approved by 174 states and became a widely adopted environmental treaty till the year 1998. This convention made biodiversity conservation an international agenda and directed states to take actions at the national level. About 197 countries ratified the agreement and agreed to take measures for safeguarding biodiversity.

According to the CBD, use of genetic resources of any region is governed by the rules set by legislation. The 42 articles have been listed in CBD.

Three major goals of the convention are:

- biodiversity protection
- sustainable use of biodiversity
- fair and equitable sharing of benefits from commercial or other utilisation of genetic resources.

All the Articles provide guidelines and practices that need to be followed. For example, Article 8 deals with the major policies for conservation of biodiversity under *in-situ* conditions. Articles 9, 10 and 14 deal with protection of biodiversity in ex-*situ* conditions, use of biological resources in a sustainable manner and environmental impact assessment. These goals are supported by actions such as research, training (Article 12), education and awareness (Article 11). The protection of our surroundings and its improvement has been given as a Directive Principles of state policy. According to the forty-second amendment of the constitution (Act of 1976), it is our fundamental duty to safeguard and improve our surroundings (environment). Articles 15 and 16 give the powers to contracting parties to decide how to get the rules implemented. Article 8(g) directs Parties to regulate the risks related to Living Modified Organisms (LMOs) developed using biotechnology at the national level. Parties have to share all data regarding LMOs with other parties that will be using or procuring these organisms (Article 19). Biosafety protocols need to be followed by the parties before the release of LMOs in the environment. This ensures safe transfer, handling and utility of LMOs which could have an impact on native biodiversity. Biosafety Protocol is a set of rules and global norms related to LMOs.

At the national level, the Biological Diversity Act was developed in 2002 in India, keeping in view the principles set by CBD for achieving the target of protecting biodiversity. This act was considered the first effective legislation developed with the goal of safeguarding the biodiversity of our country. The Act proved very helpful in protecting our natural resources, biodiversity, sustainable use of natural resources and restricting the access of our bioresources by other countries.

SAQ 1

Fill in the blanks:

a) The Stockholm Conference was held in the year ……………… .

b) IUCN category in which 90% of the population has declined in the last ten years (or three generations) is ……………… .

c) The document of Stockholm Declaration sets out ……………… Principles related to environmental protection.

d) ……………… is the number of Millenium Development Goals (MDGs) were set during Millenium declaration of the year 2000.

e) ……………… is an international organisation formed for the protection of nature and natural resources in the year 1948.

f) Living organisms are divided into ……………… number of categories as per the red list given by IUCN.

11.2.4 Convention on International Trade of Endangered Species of Fauna and Flora (CITES)

CITES is an international convention conducted with the aim of having an agreement related to the conservation of endangered species (both fauna and flora). The convention was conceptualised at a meeting of IUCN in 1963 but came into force in 1975. Initially 156 countries signed the agreement. It ensures that global trade related to wild animal and plant products such as skin, fur, bones and tusks is prohibited. The convention aimed at protecting wildlife and putting a stop to international trade of items procured from threatened animal and plant species. The agreement helped in reducing trade in many threatened species, including elephants, tigers, crocodiles, etc. A complete ban was put on hunting and capturing of threatened species and selling of products obtained from them. It lists 900 species that are endangered and cannot be exploited for trade related to their products.

Currently 183 countries are parties to CITES. Nearly 30,000 species have been protected, and about 29,000 threatened species are also restricted for international trade. It regulates cross-boundary trade in wild animals and plants and over-exploitation of species. About 110,000 plant and animal species have been brought under CITES legislation. The signatory parties need to abide by the guidelines issued by CITES. India is also a party to CITES. India signed the agreement in 1976.

Provisions of the CBD were legally recognised and implemented effectively at a national level. The implementation of CBD at a national level ensures:

i) granting of ownership of genetic information related to biological material to local communities;

ii) recognizing and protecting the traditional knowledge provided by local communities using regulation and dispute resolution through law;

iii) ensuring the involvement of these communities in widening the possibility of utility of their knowledge and practices;

iv) strictly following equitable benefit-sharing measures

CITES safeguards trade of resources for the future. It regulates the import, export, re-export and introduction of marine species.

The threatened species are sorted into various appendixes depending upon their status.

Appendix I: species that are critically endangered and are going to get extinct cannot be traded internationally.

Appendix II: species that can be traded internationally but following strict regulations.

Appendix III: species requiring international cooperation to prevent illegal exploitation.

11.2.5 Ramsar Convention

An international treaty related to a framework based on the protection of wetland areas is referred to as the Ramsar Convention. The convention was held in a city called Ramsar in Iran on February 2, 1971. The United Nations Educational, Scientific and Cultural Organisation (UNESCO) acts as the Depositary for the Convention. The convention became effective from December 21, 1975. In 1990, sixty nations agreed to the recommendations of the Ramsar convention. The treaty aimed at working together with the aim of conserving wetlands. It focuses on the formulation of effective plans and their implementation to protect the dwindling wetlands. About 168 parties signed the agreement. The convention focuses on the conservation of wetlands listed throughout the world. The main aim of the agreement is to protect wetlands along with fauna and flora and associated ecological processes. India signed this agreement in February 1982. The countries signing the agreement are called the **Conference of the Contracting Parties (COP)**. These countries meet after three years to assess and discuss the progress of the initiatives taken for the protection of wetlands. Amendments were made to the frameworks of the original convention for the COP meetings held in Paris (in 1982) and Regina (in 1987).

The countries signing the agreement had to abide by four obligations, which are as follows:

i) Conserve wetlands within a nation via changes/alterations in land-use planning.

ii) Declare at least one wetland site as Ramsar Sites (having international importance).

iii) Promote conservation of wetlands by creating nature reserves.

iv) Provide training to staff in wetland warding, research, and management and involve other countries with species or areas in common.

Other goals of the convention are:

- maintaining ecological characters of wetland areas
- promoting wise and justifiable use of wetlands and mangroves
- consulting other parties for execution of regulations for transfrontier wetlands, shared water systems and maintenance of wetland areas

About 1,200 Ramsar sites occupying an area of 1,119,000 km² have been considered as internationally important wetlands. The highest number of Ramsar sites, i.e., 176, has been reported from the United Kingdom. Pantanal in South America is the world's largest tropical wetland. It covers an area of about 185,000 square kilometres. India has 89 Ramsar sites with a total area of about 1.33 million hectares (Table 11.1).

Table 11.1: Ramsar Sites in India.

S. No.	Ramsar Sites in India	State	Area (km^2)
1.	Karaivetti Bird Sanctuary	Tamil Nadu	4.53
2.	Longwood Shola Reserve Forest	Tamil Nadu	1.16
3.	Magadi Kere Conservation Reserve	Karnataka	0.5
4.	Ankasamudra Bird Conservation Reserve	Karnataka	0.99
5.	Aghanashini Estuary	Karnataka	48.01
6.	Tampara Lake	Odisha	3
7.	Hirakud Reservoir	Odisha	654
8.	Ansupa Lake	Odisha	2.31
9.	Yashwant Sagar	Madhya Pradesh	8.229
10.	Chitrangudi Bird Sanctuary	Tamil Nadu	2.6047
11.	Suchindram Theroor Wetland Complex	Tamil Nadu	0.9423

12.	Vaduvur Bird Sanctuary	Tamil Nadu	1.1264
13.	Kanjirankulam Bird Sanctuary	Tamil Nadu	0.9689
14.	Thane Creek	Maharashtra	65.2108
15.	Hygam Wetland Conservation Reserve	Jammu and Kashmir	8.0182
16.	Shallbugh Wetland Conservation Reserve	Jammu and Kashmir	16.75
17.	Nanda Lake	Goa	0.42
18.	Karikili Bird Sanctuary	Tamil Nadu	0.58
19.	Pallikaranai Marsh Reserve Forest	Tamil Nadu	12.48
20.	Pichavaram Mangrove Forest	Tamil Nadu	14.79
21.	Gulf of Mannar Marine Biosphere Reserve	Tamil Nadu	527
22.	Vembannur Wetland Complex	Tamil Nadu	0.20
23.	Vellode Bird Sanctuary	Tamil Nadu	0.77
24.	Udhayamarthandapuram Bird Sanctuary	Tamil Nadu	0.44
25.	Vedanthangal Bird Sanctuary	Tamil Nadu	0.40
26.	Ranganathittu Bird Sanctuary	Karnataka	5.18
27.	Sakhya Sagar	Madhya Pradesh	2.48
28.	Sirpur Wetland	Madhya Pradesh	1.61
29.	Koonthankulam Bird Sanctuary	Tamil Nadu	0.72
30.	Satkosia Gorge	Odisha	982
31.	Pala Wetland	Mizoram	18.50
32.	Bakhira Sanctuary	Uttar Pradesh	28.94
33.	Bhindawas Wildlife Sanctuary	Haryana	4.11
34.	Sultanpur National Park	Haryana	1.43
35.	Haiderpur Wetland	Uttar Pradesh	69.08
36.	Wadhvana Wetland	Gujarat	6.30
37.	Thol Lake	Gujarat	6.99
38.	Khijadia Wildlife Sanctuary	Gujarat	5.12
39.	Tso Kar Wetland Complex	Union Territory of Ladakh	95.77
40.	Sur Sarovar	Uttar Pradesh	4.31
41.	Asan Conservation Reserve	Uttarakhand	4.44
42.	Kabartal Wetland	Bihar	26.20

43.	Lonar Lake	Maharashtra	4.27
44.	Saman Bird Sanctuary	Uttar Pradesh	52.63
45.	Parvati Arga Bird Sanctuary	Uttar Pradesh	7.22
46.	Samaspur Bird Sanctuary	Uttar Pradesh	79.94
47.	Beas Conservation Reserve	Punjab	64.289
48.	Keshopur-Miani Community Reserve	Punjab	3.439
49.	Nangal Wildlife Sanctuary	Punjab	1.16
50.	Nawabganj Bird Sanctuary	Uttar Pradesh	2.246
51.	Sandi Bird Sanctuary	Uttar Pradesh	30.85
52.	Sarsai Nawar Jheel	Uttar Pradesh	16.13
53.	Nandur Madhameshwar	Maharashtra	14.37
54.	Sundarban Wetland	West Bengal	4230
55.	Nalsarovar Bird Sanctuary	Gujarat	120
56.	Upper Ganga River	Uttar Pradesh	265.9
57.	Chandertal Wetland	Himachal Pradesh	0.49
58.	Hokera Wetland	Union Territory of Jammu and Kashmir	13.75
59.	Renuka Wetland	Himachal Pradesh	0.2
60.	Rudrasagar Lake	Tripura	2.4
61.	Surinsar-Mansar Lakes	Union Territory of Jammu and Kashmir	3.5
62.	Ashtamudi Wetland	Kerala	614
63.	Bhitarkanika Mangroves	Odisha	650
64.	Bhoj Wetland	Madhya Pradesh	32.01
65.	Deepor Beel	Assam	40
66.	East Calcutta Wetlands	West Bengal	125
67.	Kanjli Wetland	Punjab	1.83
68.	Kolleru Lake	Andhra Pradesh	901
69.	Point Calimere Wildlife and Bird Sanctuary	Tamil Nadu	385
70.	Pong Dam Lake	Himachal Pradesh	156.62
71.	Ropar Wetland	Punjab	13.65
72.	Tsomoriri	Union Territory of Ladakh	120
73.	Vembanad-Kol Wetland	Kerala	1512.5
74.	Sasthamkotta Lake	Kerala	3.73

75.	Wular Lake	Union Territory of Jammu and Kashmir	189
76.	Harike Wetland	Punjab	41
77.	Loktak Lake	Manipur	266
78.	Sambhar Lake	Rajasthan	240
79.	Chilika Lake	Odisha	1165
80.	Keoladeo National Park	Rajasthan	28.73

Recently 9 new sites were added to the list of Ramsar, making the total count 89 (Fig. 11.2). These include Sakkarakottai Bird Sanctuary (Tamil Nadu), Therthangal Bird Sanctuary (Tamil Nadu), Khecheopalri Wetland (Sikkim), Udhwa Lake (Jharkhand), Nagi Bird Sanctuary (Bihar), Nakti Bird Sanctuary (Bihar), Tawa Reservoir (Madhya Pradesh), Nanjarayan Bird Sanctuary (Tamil Nadu), and Kazhuveli Bird Sanctuary (Tamil Nadu).

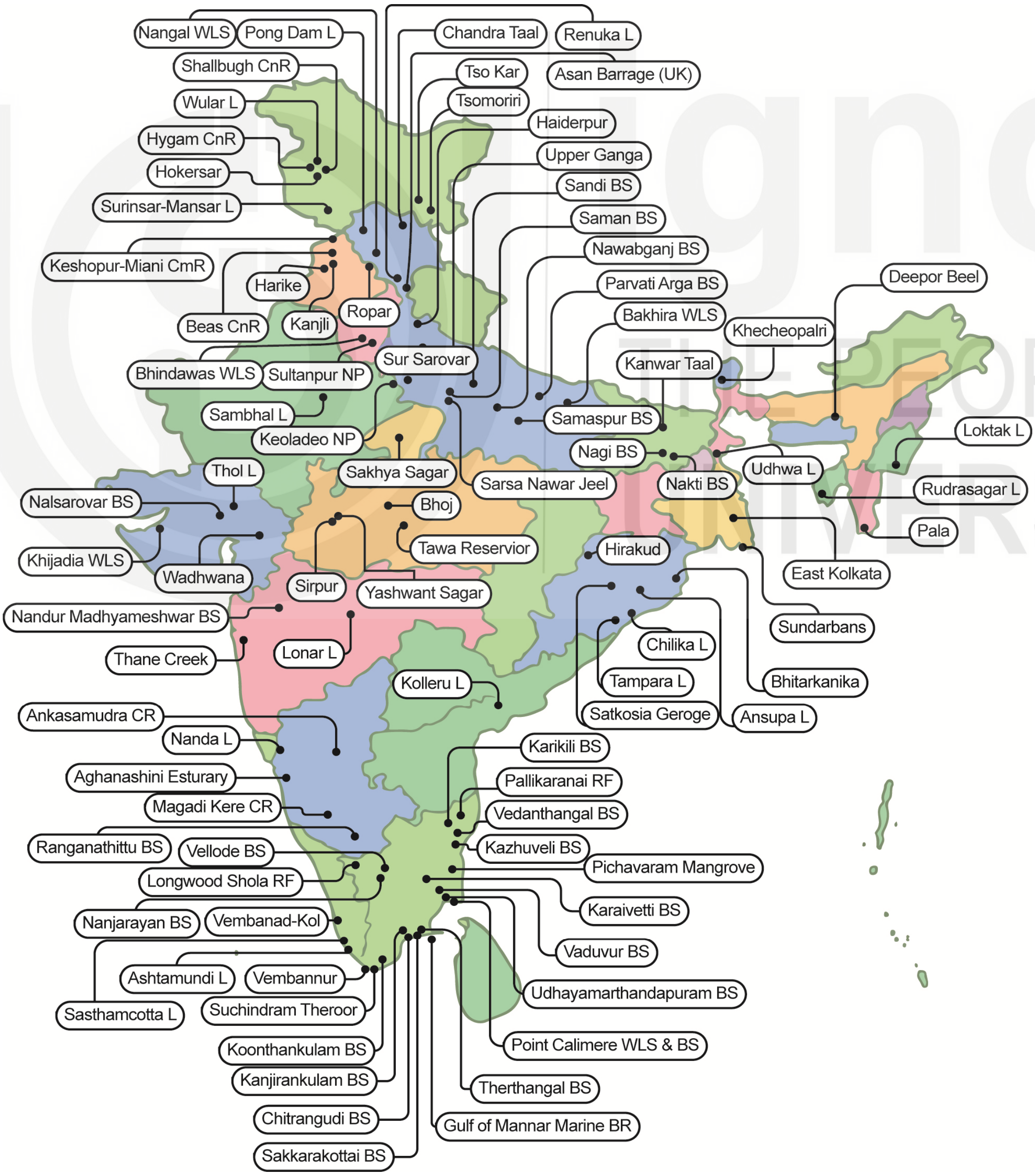

Nangal WLS
Pong Dam L
Chandra Taal
Renuka L
Shallbugh CnR
Tso Kar
Asan Barrage (UK)
Tsomoriri
Wular L
Haiderpur
Hygam CnR
Upper Ganga
Hokersar
Sandi BS
Surinsar-Mansar L
Saman BS
Nawabganj BS
Keshopur-Miani CmR
Deepor Beel
Parvati Arga BS
Harike
Ropar
Bakhira WLS
Beas CnR
Kanjli
Khecheopalri
Sur Sarovar
Kanwar Taal
Bhindawas WLS
Sultanpur NP
Sambhal L
Samaspur BS
Loktak L
Keoladeo NP
Nagi BS
Thol L
Sakhya Sagar
Sarsa Nawar Jeel
Nakti BS
Udhwa L
Rudrasagar L
Nalsarovar BS
Bhoj
Pala
Khijadia WLS
Tawa Reservior
Hirakud
Wadhwana
Sirpur
Yashwant Sagar
East Kolkata
Nandur Madhyameshwar BS
Sundarbans
Thane Creek
Lonar L
Chilika L
Kolleru L
Tampara L
Bhitarkanika
Ankasamudra CR
Satkosia Geroge
Ansupa L
Nanda L
Karikili BS
Aghanashini Esturary
Pallikaranai RF
Magadi Kere CR
Vedanthangal BS
Ranganathittu BS
Vellode BS
Kazhuveli BS
Longwood Shola RF
Pichavaram Mangrove
Nanjarayan BS
Vembanad-Kol
Karaivetti BS
Vaduvur BS
Ashtamundi L
Vembannur
Udhayamarthandapuram BS
Sasthamcotta L
Suchindram Theroor
Koonthankulam BS
Point Calimere WLS & BS
Kanjirankulam BS
Therthangal BS
Chitrangudi BS
Gulf of Mannar Marine BR
Sakkarakottai BS

Fig. 11.2: Map of India showing 89 Ramsar sites of India.

11.2.6 Bonn Convention

A Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention) was held at Bonn, Germany, in 1979. The treaty became effective in 1983. It is a treaty signed by governments of different countries under the guidance of the United Nations Environment Programme. The convention focused on conservation of land and aquatic and avian migratory species all through their range. It also establishes legal guidelines for undertaking conservation procedures at the international level. This convention has 133 parties.

11.2.7 The World Conservation Strategy (WCS)

World Conservation Strategy (WCS) was a program developed in 1980. The idea of WCS was conceptualised by the joint efforts of the United Nations Environment Program (UNEP), World Wildlife Fund (WWF) and the International Union for Conservation of Nature (IUCN). The main aim of developing WCS was to preserve genetic diversity and sustain ecological processes. It is an integration of international, national, and regional efforts to balance development with protection of environmental resources. The main objective of the strategy was to help in achieving sustainable development through the conservation of natural resources. The document

1. explains the contribution of living systems in the survival of humans and sustainable development;
2. helps to identify the major conservation issues and ways of their implementation;
3. proposes effective ways for achieving sustainability.

11.2.8 Cartagena Protocol on Biosafety (2000)

The Cartagena Protocol on Biosafety is the first international framework developed for the protection, transfer, handling and use of living modified organisms (LMOs) developed using biotechnology. The idea for the formulation of this agreement was conceptualised during the Convention on Biological Diversity. The protocol was adapted on 29th January 2000 and signed by 101 countries. The protocol came into force on 11th September, 2001. India signed the protocol on 23rd January 2001. To date, 173 countries are signatories to this protocol. The main objective of the protocol is to conserve and safeguard biodiversity from the risk posed by genetically modified living organisms. A multilateral environmental agreement managed by the United Nations Environment Programme (UNEP) was also developed. It ensures that all guidelines of the protocol are followed before any LMO is imported from or exported to other countries/territories. It ensures that safety rules are followed and risk assessment done during import of LMOs.

Global biodiversity framework (GBF)

Kunming-Montreal Global Biodiversity Framework is an action plan for protection of biodiversity and prevention of its further loss. The framework was developed in the year 2020 and has set a time frame for biodiversity conservation by the year 2030 and that for recovery and restoration of biodiversity loss as 2050. The plan includes measures to stop loss of nature and restore it up to 30% of the planet's surface area and 30% of degraded ecosystems by 2030. It also proposes financial assistance/aid to developing countries. This initiative for biodiversity conservation is supported by IUCN. The major components of the GBF are:

- protection and conservation of areas *via* effective management as per the list of protected and conserved areas given by IUCN;
- protection of species through a Global Species Action Plan. This goal aims at developing and implementing an effective and comprehensive programme of actions to conserve species;
- restoration of ecosystems *via* reversal of loss in green area, integrity and connectivity to optimise their contributions to biodiversity and ecosystem services;
- protection of planet's land surface (about 30%) by 2030 *via* implementation of effective area-based conservation measures;
- retention of intact ecosystems and restoration of degraded ecosystems.

The Kunming-Montreal Global Biodiversity Framework has 23 action-oriented global targets to be achieved by the year 2030. Actions taken for achieving each target need to be implemented consistently and in accordance with the Convention on Biological Diversity and its protocols. Figure 11.3 shows the major goals of GBF.

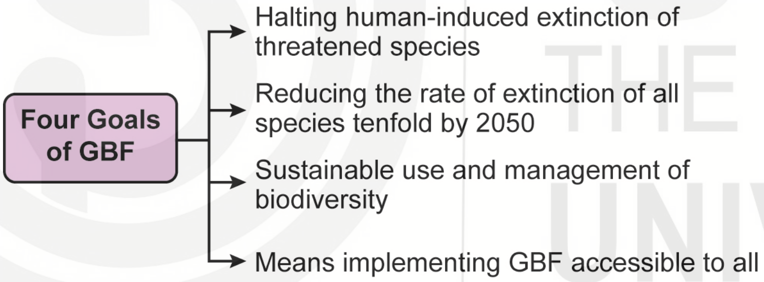

Four Goals of GBF
Halting human-induced extinction of threatened species
Reducing the rate of extinction of all species tenfold by 2050
Sustainable use and management of biodiversity
Means implementing GBF accessible to all

Fig. 11.3: Major goals of GBF.

Target 1: Planning and Management of Areas to Reduce Biodiversity Loss

Land and sea-use changes need to be addressed effectively for all areas so as to bring ecological integrity while keeping the rights of indigenous peoples and local communities.

Target 2: Restoration of 30% of all Degraded Ecosystems

At least 30% of degraded terrestrial/land areas, inland water, and marine and coastal ecosystems need to be restored by 2030. This would ensure proper functioning of ecosystems and protect biodiversity.

Target 3: Conservation of 30% of Land, Waters and Seas

At least 30% of the area with terrestrial and inland water and marine and coastal areas of particular importance in terms of biodiversity, ecosystem functions and services need to be conserved effectively via area-based conservation measures.

Target 4: Halt Species Extinction, Protect Genetic Diversity, and Manage Human-Wildlife Conflicts

Ensure that appropriate actions are taken for putting a stop to human-induced extinction of threatened species. Maintenance and restoration of the genetic diversity within and between populations of native, wild and domesticated species need to be done by *in- situ* and *ex-situ* conservation practices. Human-wildlife conflict also needs to be minimised.

Target 5: Ensure Sustainable, Safe and Legal Harvesting and Trade of Wild Species

Ensure that wild species are sustainably used and their overexploitation is prevented so that the impact on non-target species and ecosystems can be reduced.

Target 6: Reduce the Introduction of Invasive Alien Species and Minimise Their Impact

Minimise/reduce the effect of invasive alien species on biodiversity. Identifying and managing the ways so that the establishment of invasive alien species can be prevented (about 50%) by 2030.

Target 7: Reduction in Pollution

Reduce pollution so that harmful effects of pollution on biodiversity can be prevented and ecosystem functions/services are retained. These may be done by **(a)** minimising nutrient loss from the environment through efficient nutrient cycling; (b) reducing the effect of pesticides and hazardous chemicals through integrated pest management; and (c) preventing, reducing and eliminating plastic pollution.

Target 8: Minimising the Impacts of Climate Change on Biodiversity and Build Resilience

The impact of climate change and ocean acidification on biodiversity can be reduced, and resilience needs to be increased through mitigation, adaptation, and promotion of nature-based solutions and/or ecosystem-based approaches.

Target 9*:* Management of Wild Species *via* Sustainable Ways

Promoting sustainable practices and use of wild species so that social, economic and environmental benefits can be provided to people that are dependent on biodiversity.

Target 10: Enhancement of Biodiversity and Sustainability in Agriculture, Aquaculture, Fisheries, and Forestry

This should be done through sustainable management of areas under agriculture, aquaculture, fisheries and forestry. Sustainable use of biodiversity following agroecological and other innovative approaches**.** This contributes to the resilience and long-term efficiency and productivity of ecosystems *via* the maintenance of food security and the conservation and restoration of biodiversity.

Target 11: Restoration, Maintenance and Enhancement of Nature's Contributions to People

Nature-based solutions and/or ecosystem-based approaches need to be implemented for the benefit of all people and nature. Pollution of air and water needs to be controlled, climate change needs to be mitigated and adapted to, and soil health needs to be maintained. Besides this, the need for reduction of disease risk, as well as protection from natural hazards and disasters, also needs to be minimised.

Target 12: Increase in Green Spaces and Improvement in Urban Planning for Human Well-Being and Biodiversity

Increase the area, quality and connectivity; access to; and benefits from green and blue spaces in urban and densely populated areas. It ensures conservation and sustainable use of biodiversity via improvement in areas through urban planning**.**

Target 13: Increasing the Share of Benefits from Genetic Resources, Digital Sequence Information and Traditional Knowledge

Implementation of effective legal and capacity-building measures to ensure that traditional knowledge associated with genetic resources and the benefits arising from the utilisation of genetic resources are equally shared.

Target 14: Integration of Biodiversity in Decision-Making at Every Level

Integration of biodiversity and its multiple values into policies, regulations, planning and development processes at all levels of government and across all sectors.

Target 15: Reduction of Biodiversity-Related Risks and Negative Impacts

Regular monitoring, assessment and study of impacts on biodiversity, especially for large, multinational companies and financial institutions, supply and value chains. It ensures that negative impacts on biodiversity are reduced while positive impacts are enhanced.

Target 16: Enable Sustainable Consumption Choices for Reduction of Waste and Overconsumption

Ensure that people are encouraged to make sustainable consumption choices. Supportive policy, legislative or regulatory frameworks need to be established. Improvement in education and access to relevant and accurate information by 2030 so as to reduce the global footprint by reducing consumption.

Target 17: Strengthen biosafety and restrict use of biotechnology.

Establish and implement biosafety measures as mentioned in Articles 8(g) and 19 of the Convention on Biological Diversity.

Target 18: Reduction in Harmful Incentives and Increase in Positive Incentives for Biodiversity

Remove harmful effects of biodiversity in an effective and equitable way worth at least $500 billion per year by 2030. It also emphasises scaling up positive effects of biodiversity via conservation and its sustainable use.

Target 18: Allocate an amount of $200 billion per year for biodiversity from all sources.

Substantial increase in the level of financial resources in accordance with Article 20 of the Convention. Implementation of national biodiversity strategies and action plans, mobilising at least $200 billion per year by 2030.

Target 20: Capacity-Building, Technology Transfer, Scientific and Technical Cooperation for Biodiversity

Strengthen capacity-building and development; access to and transfer of technology; and promote development of and access to innovation and technical and scientific cooperation to meet the needs for effective implementation, particularly in developing countries. Development of technology and joint scientific research programmes for the conservation and sustainable use of biodiversity.

Target 21: Biodiversity Action Guided by Knowledge

Ensure that knowledge in the form of data is available for decision-makers and practitioners so that an integrated management approach for biodiversity can be developed. Communication, education, monitoring, research, traditional knowledge management, innovation, practices and technologies of indigenous peoples and local communities need to be accessed in accordance with national legislation.

Target 22: Ensure Participation of All in Decision-Making and Information Related to Biodiversity

Ensure equal, effective and gender-responsive participation in decision-making and access to justice and information related to biodiversity by indigenous peoples and local communities.

Target 23: Ensure Gender Equality and a Gender-Responsive Approach for Biodiversity Action

Ensure gender equality in the implementation of the framework and ensure that equal opportunity is given to the female gender in achieving major objectives of the convention.

Besides the targets set under this initiative, other practices such as innovative financing schemes were started. Alternate technologies such as the use of green technologies, sustainable agricultural practices and clean energy solutions are promoted to minimise the damage to biodiversity. Advanced monitoring and surveillance technologies like satellite imagery, drones, and artificial intelligence for real-time monitoring have been encouraged. Collaboration between scientists, policymakers and local communities has also been encouraged to achieve the targets within the specified time. Partnerships and collaborations at the international level among governments, private entities and indigenous communities are encouraged to address biodiversity challenges and achieve conservation targets.

SAQ 2

a) Answer the following statements in one word:

i) Number of threatened species listed in the CITES list.

ii) An international framework based on the protection of wetland areas.

iii) Total number of Ramsar sites in India.

iv) The Cartagena Protocol on Biosafety is the first international framework developed for the protection, transfer, handling and use of these organisms developed using biotechnology.

v) A global action plan developed for protection of biodiversity and prevention of its further loss with the time frame of 2030.

vi) Total number of targets set under the Kunming-Montreal Global Biodiversity Framework.

b) State whether the following statements are 'True' or 'False':

i) India is not a member of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) adopted in 1975.

ii) The Convention on Biological Diversity (CBD), aiming at biodiversity protection, was organised in Rio de Janeiro on 5th June 1992.

iii) Sharing of benefits from commercial or other use of genetic resources in a justified manner and equally is the major goal of the CBD convention.

iv) The Convention on the Conservation of Migratory Species of Wild Animals was conceptualised with the aim to conserve only migratory bird species all through their range.

11.3 BIODIVERSITY CONSERVATION AT NATIONAL LEVEL

The Indian constitution also well defines environmental protection. Article 48A and Article 51A(g) of the Directive Principles of State Policy state that the States and all citizens hold responsibility towards their maintenance of their surroundings (environment). According to Article 51A(g) of the Constitution, every citizen should protect and take care of the environment and living creatures. According to Article 48A, the state needs to take measures to conserve and safeguard the environment, including forests, water bodies and living beings, and have concern for living beings.

A legal policy framework related to biodiversity has been developed. The Forest Act of 1927, the Forest (Conservation) Act of 1980, the Wildlife

(Protection) Act of 1972, the National Wildlife Action Plan of 1983 and the Environment (Protection) Act of 1986 are the major legislations related to the protection of natural resources such as forests and wildlife. Many initiatives have been taken by the Indian government to protect and conserve biodiversity.

The Wildlife (Protection) Act, enacted by the central government in 1972, aimed at the protection of wildlife. As per this act, many areas have been declared as reserved areas. These include national parks, sanctuaries, conservation reserves, and community reserves. The Wildlife Crime Control Bureau has been established for control of illegal trade in wildlife, including endangered species.

The National Forest Policy, 1988, deals with issues such as the sustainable use of forests and the protection of ecological areas such as mountain and island ecosystems. The National Conservation Strategy 1992 postulates the requirement of biodiversity conservation.

Wetland (Conservation and Management) Rules 2010 were framed to protect wetland areas of the country. The National Plan for Conservation of Aquatic Ecosystems for the management of wetlands, including Ramsar sites in the country, was also implemented. Schemes such as ‘Integrated Development of Wildlife Habitats‘ sponsored by the central government with the component ‘Recovery of Endangered Species‘ were launched. The scheme was launched to restore the status of endangered species such as the Hangul, Snow leopard, Swiftlet, Nilgiri tahr, Sangai deer and many more**.**

The state governments provide technical and financial help under various centrally sponsored schemes, such as ‘Integrated Development of Wildlife Habitats’, and projects (such as Project Tiger) aimed at conserving wildlife.

11.3.1 National Framework for Biodiversity Conservation

Various wildlife acts with the goal of protection of wildlife were implemented by the state and central governments of India. Many schemes related to conservation of threatened species were also initiated. For example, Project Tiger was launched in 1973, Project Crocodile in 1954, Project Lion in 1952 and Project Elephants in 1991.

The Indian Board of Wildlife (IBWL), a government body, was constituted by the government of India in 1952. The main goal was to ensure measures for protection of species diversity were taken in the country. Protected areas were established, resources were used sustainably and unethical practices that can lead to biodiversity loss have been restricted.

The Indian government passed various acts related to environment and biodiversity protection. These include the Fisheries Act 1897, the Indian Forests Act 1927, the Mining and Mineral Development Regulation Act 1957, the Prevention of Cruelty to Animals 1960, and the Wildlife Protection Act 1972. Water (prevention and control of pollution) Act 1974, Forest Conservation Act 1980, Air (prevention and control of pollution) Act 1981, Environment Protection Act 1986, Biological Diversity Act 2002, Scheduled Tribes and other traditional forest dwellers (recognition of rights) Act 2006.

Various policies related to environment and biodiversity conservation include National Forest Policy, National Conservation Strategy and Policy Statement on Environment and Development. National Policy and Macro-level Action Strategy on Biodiversity, National Biodiversity Action Plan (2009), National Agriculture Policy, National Water Policy and National Environment Policy (2006).

National Biodiversity Strategy and Action Plan (NBSAP)

This Forum is a global partnership developed with the aim of supporting countries in implementing the UN Convention on Biological Diversity (CBD) and its strategic plans, including biodiversity conservation. The countries that are part (parties) of CBD need to develop and implement NBSAPs so that national targets can be set, and accordingly, plans, programmes and policies for biodiversity conservation can be implemented. NBSAP Forum is funded by the Global Environment Facility (GEF) in partnership with other agencies such as the Secretariat of the Convention on Biological Diversity (SCBD), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

Forest Protection Act

The Forest Protection Act was implemented in 1927. The act focused mainly on protection of forests. Different types of forest areas, such as reserved and protected forest areas, forests associated with villages, and private forests, have been protected under this Act. According to this act, any state can declare forest or wastelands as reserved/protected forests. State governments have banned deforestation in reserved forests. The deforestation and related activities are punishable, and violations can result in fines/penalties or imprisonment or both. Some reserved forest areas called village forests have been allocated to villagers for protection and conservation. The Act focuses on forest conservation via enforcement of rules, regulations and criminal prosecutions.

The Forest (Conservation) Act was enacted by the central government in 1980. The Act was implemented to limit cutting of forest trees and associated damage to the environment. An approval by the central government for use of forest areas for non-forest purposes is compulsory. According to this act, state governments have the power to take steps for safeguarding forests by enforcing laws and putting regulations in place or preventing forest areas from damage such as conversion into agricultural land, pasturing or other activities. The area reserved for forests can only be used for forestry purposes, but if it needs to be used for other purposes, prior approval from the central government is required. If cutting of some trees is done in any area, replacement needs to be made by economically important tree species (reforestation).

The main aims and objectives of the Act are:

- protection of forest areas
- bringing environmental stability and restoration of ecological balance
- protection of natural inheritance

- prevention of soil erosion near rivers, lakes and reservoirs
- afforestation to increase forest cover
- enhancing efficiency of forests for production
- wise use of forest products
- check conversion of forest area for other needs

Under section 112, the state government is empowered to develop regulations for the protection of forests to keep a check on:

- damage to any part of forest
- deforestation for timber and utilisation of products from protected forests
- restricting cattle feeding in forest areas
- prohibit hunting in reserved forests
- giving a licence to inhabitants living near the protected forests for use of timber and forest produce.

According to section 110, any area having trees can be designated as reserved or protected forests by the state government. An imprisonment of at least six months or a fine of Rs 500 or more or both is the penalty decided for a person who violates any of the laws of this act and commits offences such as:

- falls or burns of any reserved tree;
- clear the land for cultivation in any protected forest;
- does not take required steps for preventing fire in forests;
- Prohibition on carrying out activities such as burning lime or charcoal or collecting/removing any type of forest produce;
- allows cattle to graze and damage reserved forest.

The Act was amended in 1988. This was done to include clauses related to the welfare of people living in or near forests. According to this amendment, forest areas cannot be leased to any person except the government, and reserved forest areas can only be removed with the permission of the central government. The practices related to conservation and expanding the reserved forest area are permitted. According to an amendment made in 1992, non-forest activities without felling of trees or cutting trees in a limited number for activities such as laying of electricity cables, surveys related to earthquakes, investigation, and boring are permitted *via* permission of the central government. Non-forest activities are prohibited in reserve forests, but only the cultivation of native species is permitted. Monoculture plantations are prohibited. A prior approval is required from the central government, accompanied by details such as a cost-benefit analysis and an environmental impact assessment for ecological and socio-economic aspects for any kind of non-forest activity. The National Forest Commission was constituted by the Ministry of Environment, Forests and Climate Change, Government of India, which monitors the progress of the work related to conservation of forests and wildlife. A comprehensive long-term plan (20 years), i.e., a forestry action programme, was developed to bring one third of the country's area under tree/forest cover.

11.3.2 Wildlife Protection Act

The Indian government has been making tremendous efforts for the protection of wildlife. The Madras Elephant Preservation Act 1879, the Wild Birds and Animals Protection Act 1912, and the Indian Forest Act 1927 are the major laws implemented long ago for the protection of wildlife. Wildlife Rules passed in 1971 imposed a ban on trade related to rare and endangered species and the products obtained from them. The Wildlife Protection Act, developed in 1972, aimed at the protection of wildlife in India. This Act was adopted by all the states except Jammu and Kashmir. The major goal of this act was protection of endangered species. According to the Wildlife Protection Act, 1972, “wildlife” includes animals, bees, butterflies, crustacea, fish and moths and any kind of vegetation (whether aquatic or terrestrial) found in that habitat. The Act had provisions for complete prohibition on hunting or damage to wildlife. Several amendments were made in the act. An advisory board for the regulation of activities such as hunting of animals, trade related to wild animals, and establishment of reserved areas such as sanctuaries and national parks was constituted.

India joined the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1976. According to this trade, import and export of endangered animal and plant species, their products and profitable activity are strictly prohibited. The growing demand for animal products such as skin, fur, tusks and bones was one of the major reasons for the overexploitation of wildlife. Amendments were made in the Wildlife Act, and an advisory board was set up for the regulation of the hunting of animals, trade in wild animals, and establishment of national parks. State boards were also constituted to keep a check on illegal activities.

The Act focuses on:

- maintenance of essential ecological processes and life-supporting systems;
- preservation of biodiversity;
- ensuring protection and conservation of wildlife.

According to section 6 of this Act, the state government or the union territory can establish a Wildlife Advisory Board. Section 18 of this Act declares that an ecologically important area can be declared a sanctuary by the government in order to protect wildlife with its environment. Under section 15, state governments can declare an area which is of good ecological, floral, faunal, or geomorphological importance as a national park with the objective of protecting wildlife with its environment. The hunting of animals is strictly prohibited under this Act except in the condition when it proves a threat for human life or is disabled or diseased beyond recovery.

The violation of these laws by a person can entitle him/her to imprisonment for three years, a penalty fine of Rs. 25,000/-, or both. Projects Lion (1972), Project Tiger (1971), and Project Crocodile (1974) were the major initiatives taken for the protection of important species of our country.

11.3.3 Environment Protection Act (EPA), 1986

The Environment (Protection) Act of 1986 was framed to implement strict actions for conservation of the environment. This act was implemented after the incident of the Bhopal gas tragedy (1984). The Act focuses on the regulation of all those substances/elements that are present in such amounts in the environment that affect the environment to a significant extent. The regulations proposed in this act aimed at the protection of various components of the environment, such as water, air, and land. The main goals of the act are:

- Conservation and protection of the environment;
- prevention of injury or damage to all the living organisms and property;
- maintenance of a peaceful relationship between humans and their environment.

The Act provides a complete framework for coordination of activities/initiatives covered under the Water and the Air Acts implemented by central and state governments. Under this act, strict measures are taken to protect and improve the environment by controlling pollution and preventing any harm to living beings, including humans and property. According to Section 11 of this Act, the central government has the power to:

- instruct each state to set up a ‘Green Bench’ court to settle issues or Public Interest Litigation (PIL) cases related to environmental deterioration which might be detrimental to the life of all citizens;
- plan and execute nationwide programmes for the control and reduction of environmental pollution;
- coordinate activities of state government with other authorities;
- define standards for improving the environment in various ways and take necessary action for reducing emissions or release of contaminants into the environment;
- lay down procedures for disposal and treatment of harmful/toxic substances so as to safeguard against accidents caused due to environmental pollution and suggest remedial measures;
- keep a check on manufacturing processes that might be the cause of environmental pollution;
- establish environmental laboratories and institutes that can consistently analyse environmental pollutants so that the quality of the environment can be improved.
- The act prohibits the release of any environmental pollutant beyond permissible limits and the handling of hazardous substances without following the prescribed safety procedures.

- It focuses on prevention and mitigation of environmental pollution and intimation about the source of environmental pollution to authorities.
- It gives immense powers to the central government for the collection of air, water, and soil samples for analysis.
- The act ensures that the violation of the norms of the law shall be subjected to five years' imprisonment or a penalty of up to one lakh rupees or both.
- The act also states that the person responsible for the pollution shall be held responsible and has to pay the expenses for the remedial measures. An amendment was made in the Environment (Protection) Rules in 1994. The need for a procedure called the 'Environmental Impact Assessment' for various development projects was emphasised.

Corresponding to this act, Environment Protection Rules were framed in 1986. According to these rules, the central government has the power to get the environmental pollution controlled and reduced by taking appropriate measures. A proper coordination in actions should be there between central government and state governments for effective execution of the act. The National Environment Tribunal Bill 1992 was developed to provide relief and compensation to the public in case of damage caused from an accident that occurs during the handling of any harmful material and its disposal.

11.3.4 Biodiversity Act 2002

The Biological Diversity Bill was implemented in December 2002. The main aim of the Act is to protect the biodiversity of the country and associated traditional knowledge. It also focused on the allocation of benefits after their use by other countries and organisations. The Act focuses on the access of the genetic resources and the development of policies and programmes for conservation and protection of biological resources and associated knowledge. Under this act, state-level biodiversity boards were established in various states such as Karnataka, Goa, Punjab, Madhya Pradesh, Arunachal Pradesh, Nagaland, Himachal Pradesh, Kerala and West Bengal. Local level biodiversity committees are also constituted to achieve the target of biodiversity conservation, its justifiable use and equal sharing of profits coming from the utilisation of bioresources.

The National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs) and Biodiversity Management Committees (BMCs) were established to attain the target of biodiversity conservation. Biological diversity rules were also framed in agreement with the provisions of the Act. All the bodies, such as the NBA, SBB and BMCs, need to consult each other regarding the utility of biological resources/related knowledge in their domain and work for the protection, justifiable use and proper listing of biodiversity.

Approval from the NBA is needed for the use of biological resources and/or associated knowledge by foreign nationals/organisations and for sharing results of research for any biological resources with foreign nationals/organisations. The main focus of the rules is protection, justifiable use and benefit sharing of biological resources. However, Indian citizens/entities/local people, including local practitioners such as '*vaids'* and '*hakims',* have been allowed to have free access to use biological resources within the country for self-utility, medicinal purposes and research purposes.

Terms and conditions to ensure security during equal sharing of benefits are ensured. Approval of the NBA is required prior to opting for intellectual property rights (IPRs) in or outside India for a discovery from research or information on a bioresource obtained from India. The benefits obtained in the form of money, fees, and royalties need to be given to the National Biodiversity Fund that will be used for conservation and growth of areas.

11.3.5 Wildlife (Protection) Amendment Bill 2002

Certain amendments in the Wildlife Protection Act were made to increase the protection of species under the law. The provision for an increase in punishment for illegal wildlife trade has been provided in the bill. It also ensures rights for the people living in the vicinity of the forest areas/nature and dependent for livelihood on natural forest resources. It permits activities like grazing or movement of livestock and justified use of water by local communities. It protects the rights of the people. It also gives legal uplift to the National Board for Wildlife and Wildlife Advisory Board. It also rationalises the process of declaration of sanctuaries and national parks for protection of wildlife and biodiversity conservation. It bans the commercial sale of forest produce obtained from national parks and sanctuaries for better management of wildlife. Enhancement of penalties for defaulters decided according to the Act.

11.3.6 Biosafety Act / Biosafety Framework

Biosafety framework deals with a set of rules developed for the use of genetically modified living organisms (GMOs). These rules are governed by legislation. The Ministry of Environment and Forests in 1989 issued guidelines for LMOs under the EPA Act. Use and other activities related to genetically modified organisms in India are regulated by the EPA. The regulations deal with the development, utilisation, trade (import, export) and storage of genetically transformed microorganisms. The 1989 Rules related to Genetically Engineered Organisms or Cells banned the release of GMOs in India. In 1998 the guidelines for conducting research related to genetically transformed plants were revised. The need for data collection related to toxicity and allergic reactions for seeds that are used as food and ruminants which consume transgenic plants was realised. Thus, the 1998 guidelines focused on the concept that transgenic crops can be both ecologically safe and cost-effective.

Biosafety guidelines were issued in 1990 by the Department of Biotechnology, a body under the Ministry of Science and Technology. These guidelines permit the use of GMOs but with a clause that they are not harmful to health. The major amendments were made in 1994 and 1998. The 'Recombinant DNA Safety Guidelines' of 1990 and 'Revised Guidelines for Safety in Biotechnology' given in 1994 give directions related to control of GMOs and good laboratory practices for these organisms in the field of agriculture and pharmaceuticals.

The Indian biosafety regulatory framework (comprising the 1989 Rules and the DBT guidelines) deals with all the activities related to genetically transformed living organisms. The major activities include research and development of genetically modified organisms, technologies for vaccine development and products obtained through rDNA technology. The genetically modified organisms used in various production units are also covered.

The checking of the suitability of the transgenic crop for use in the agriculture sector and evaluation of its cost-effectiveness to farmers was considered the main part of the process related to the approval of transgenic crops. The biosafety evaluation was a very essential part of the process. The field-testing of transgenic cotton for large-scale cultivation was permitted by the government in India in July 2000.

SAQ 3

State whether the following statements are ‘True’ or ‘False’:

a) The wildlife acts were adopted by all the states except Jammu and Kashmir.

b) The reserved forests allocated to a village's people are known as village forests.

c) According to the Wildlife Amendment Bill 2002, statutory status is given to the National Board for Wildlife.

d) Environmental Protection Act primarily focuses on the removal of pollution from the environment.

e) A set of rules for the use of genetically modified organisms (GMOs) was developed in the biosafety framework.

11.4 SUMMARY

- Biodiversity is facing a threat in today’s fast-changing world. Habitat destruction and climate are the two factors affecting the biodiversity. The development of a legal framework for biodiversity conservation was realised.

- Various conventions, protocols and multilateral agreements focusing on environmental conservation and the production of biodiversity have been developed and implemented. At the international level, the Convention on Biological Diversity, CITES, the Ramsar Convention, and the Bonn Convention are some of the regulations implemented with the aim of safeguarding biodiversity.

- Kunming-Montreal Global Biodiversity Framework is a framework for the protection of biodiversity developed in the year 2020. The time frame for different goals for biodiversity conservation needs to be achieved by the year 2030, and recovery/restoration needs to be done by 2050.

- India has adopted several policies and designed a framework to safeguard biodiversity. National policies and laws incorporating biodiversity conservation practices have been developed. The central and state governments have approved regulations for the conservation of the environment.
- Forest Protection Act, Wildlife Protection Act, and Biodiversity Act 2000 are some of the main legislations framed by India for the protection of the environment and protection of biodiversity.

11.5 TERMINAL QUESTIONS

1. List the main features of CBD.
2. Why is CITES considered an important step towards protection of biodiversity? Justify the statement, giving a suitable explanation.
3. Describe the act that implemented regulations related to genetically modified organisms at a global level.
4. Which environmental legislation safeguards the forests in India? Give its key features?
5. List the possible reasons for the decrease in forest cover of India even after the implementation of the Forest Protection Act.
6. Implementation of the Biodiversity Act 2000 is very important for the conservation of biological resources of India. Justify the statement, giving a suitable explanation.
7. Why is the Environmental Protection Act (EPA) considered an important legislative regulation?
8. List the major features of the Global Biodiversity Framework.
9. Which is the main convention related to the protection of wetlands? What are the major steps decided for wetland conservation?

11.6 ANSWERS

Self-Assessment Questions

1. a) 1972
   b) critically endangered
   c) 26
   d) 8
   e) IUCN
   f) nine
2. a) i) 29,000
      ii) Ramsar convention.

iii) 89

iv) living modified organisms (LMOs)

v) Kunming-Montreal Global Biodiversity Framework

vi 23

b) i) False; ii) True; iii) True; iv) False

3. a) True; b) True; c) False; d) True

Terminal Questions

1. Refer to Section 11.2.
2. Refer to Section 11.2.
3. Refer to Section 11.2.
4. Refer to Section 11.3.
5. Refer to Section 11.3.
6. Refer to Section 11.3.
7. Refer to Section 11.3.
8. Refer to Section 11.2.
9. Refer to Section 11.2.

Acknowledgement for Figures

Fig. 11.1 :	Bullock, R., Ralph, G., Stump, E., Al Abdali, F., Al Asfoor, J., Al Buwaiqi, B., Al Kindi, A., Ambuali, A., Birge, T., Borsa, P., Di Dario, F., Everett, B., Fennessy, S., Fonseca, C., Gorman, C., Govender, A., Ho, H., Holleman, W., Jiddawi, N., Khan, M., Larson, H., Linardich, C., Matiku, P., Matsuura, K., Maunde, C., Motomura, H., Munroe, T., Nair, R., Obota, C., Polidoro, B., Russell, B., Shaheen, S., Sithole, Y., Smith-Vaniz, W., Uiblein, F., Weerts, S., Williams, A., Yahya, S., Carpenter, K. (2021). The conservation status of marine biodiversity of the Western Indian Ocean. Gland, Switzerland: IUCN. vii + 32 pp. https://portals.iucn.org/library/node/49295
Fig. 11.2 :	https://rsis.ramsar.org/?f%5B0%5D=regionCountry_en_ss%3AIndia
Fig. 11.3 :	https://theiashub.com/free-resources/mains-marks-booster/international-initiatives-and-agreements-on-biodiversity

UNIT 12

CONSERVATION AND MANAGEMENT OF BIODIVERSITY

Structure

12.1 Introduction

Objectives

12.2 Biodiversity Conservation Methods

In Situ Conservation

Ex Situ Conservation

Traditional Ecological Knowledge in Biodiversity Conservation

12.3 Summary

12.4 Terminal Questions

12.5 Answers

12.1 INTRODUCTION

Biodiversity includes all species of living organisms. Living organisms act as a huge resource, as they provide us essential products required for the sustenance of life. Besides fulfilling the basic requirements, many essential functions are also performed by biological diversity. Biodiversity possesses both direct and indirect value. The direct value includes the provision of essential items such as food, fodder, wood, medicines, etc. Indirect benefits provided by biodiversity include carbon fixation through photosynthesis, the water cycle, soil formation, regulation of climate, and preservation of the environment. Social values, including aesthetic, cultural, recreational, educational, ecotourism, and research benefits, are also provided by biodiversity. A major proportion (about 40%) of the global economy is derived from biodiversity. The diversity of species is declining with each passing year. The major reason for the decline in biodiversity is anthropogenic activities such as overuse of resources, pollution, and climate change. All these have led to degradation of habitats. Studies have predicted a huge loss of species (about one million) in the future throughout the world. It is estimated that

60,000 to 1,00,000 species which have good economic value are under threat of extinction. Hence, realising the fact that biodiversity is under threat, declining rapidly and important for the sustenance of life on earth, conservation of biodiversity becomes essential. The protection of biodiversity is important because

- it offers immense uses.
- It maintains essential processes that sustain human survival.
- It carries ethical, social and economic importance.

The efforts for protecting biodiversity are gaining momentum throughout the globe. Many areas have been categorised as protected zones, international conventions have been organised, treaties have been signed, and legislative frameworks have been developed. This Unit discusses the importance of biodiversity, different levels of biodiversity and the need for its conservation. Various methods of biodiversity protection (*ex situ and in situ* conservation techniques) will also be discussed.

Objectives

After studying this unit, you should be able to:

- ❖ describe various types of biodiversity;
- ❖ explain the objective of biodiversity conservation;
- ❖ describe various biodiversity conservation methods;
- ❖ enlist main features of *in situ* and *ex situ* conservation methods; and
- ❖ describe initiatives for biodiversity protection throughout the world.

10.2 BIODIVERSITY CONSERVATION METHODS

Protection of biodiversity includes efforts to maintain biodiversity and its management to attain sustainability in the present and future. Conservation strategies can be based on species, habitat or ecosystem. Conservation also relates to actions related to resource utilisation within justifiable boundaries. Major principles of the global biodiversity strategy listed in Box 12.1

Biodiversity can be safeguarded and maintained by a variety of genes within a population, a high species count within an area or ecosystem. A greater number of species and diverse populations are called high biological diversity. High inherent variety depends upon the species being well adapted to surroundings. They are less prone to extinction. High genetic diversity of species can easily be conserved. The protection of one species does not conserve the whole genetic diversity. Existence of numerous species in an area suggests the presence of living conditions essential for their survival. The presence of many species in an ecosystem is called ecosystem diversity. It shows long-term stability, and all the species get conserved.

Different approaches followed for biodiversity protection include:

- Habitat conservation

- Species-based conservation
- Species and ecosystem conservation
- Integrated landscape
- Mixed

Box 12.1: Global Biodiversity Strategy

Major principles listed in the global biodiversity strategy are:

- Every living organism is unique and should be cared for by humans.
- The biodiversity is valuable at local, national and global levels; therefore, its protection is a must.
- The benefits from the biodiversity should be shared among nations and the people. Its protection is a must.
- Biodiversity conservation is important for sustainable development.
- Development of policies and organised reforms needs to be done to ascertain that money allocated for the cause is used effectively.
- The biodiversity needs to be protected at local, national, and global levels.
- Public awareness and concern play an important role in biodiversity conservation.
- Reliable information should be shared with policy makers so that the necessary action can be taken.

Habitat conservation

In this approach, areas of occurrence of biodiversity are protected. It emphasises safeguarding and organising ecosystems and habitats so that species present in the area are maintained. For example, the Great Barrier Reef in Australia is conserved using the approach of habitat conservation. The park manages to protect the reef and its inhabitants by limiting human activities such as fishing and tourism and improving water quality. Some species rapidly respond to alterations in an ecosystem. These species are called **indicator species** and prove very useful in biodiversity conservation. The species number changes with a change in the environmental conditions. Amphibians, birds, molluscs, fungi, and corals act as indicator species. This approach might not be suitable for the protection of all species and the whole genetic diversity. Threatened species can be maintained only through conservation measures.

Species conservation

In this approach, species need to be considered first for conservation, followed by ensuring the availability of resources. This strategy helps in the conservation of threatened and valuable species (Box 12.2). Individual species important for the functioning of ecosystems, or iconic flagship species (species that are globally recognised), are considered for conservation. The species that appeal to the public and help in the protection of other species present in that area are called **flagship species**. These species are charismatic, recognised, popular, large and furry. For example, giant pandas and gorillas.

The government of China has taken steps to protect the giant panda (*Ailuropoda melanoleuca*) by restoring its habitat and following practices such as captive breeding.

The action plans for recovery, development and conservation of the species are required. The conservation approach needs to be supported by the implementation of legislation related to the protection of species, trade restrictions for species products, and invasive and indigenous species. The biggest drawback of the method is that it only ensures the survival of a single flagship species but not the other ones inhabiting the same area.

Box 12.2: International action to conserve species

An approach related to the protection of species was followed by the Species Survival Commission (SSC) under the aegis of IUCN – The World Conservation Union. The endangered species present all over the globe are identified and enlisted by SSC. Scientific criteria for the safeguard of the species are prepared.

The SSC is a global network in which members are the experts or specialists having an expertise in geography and/or taxonomy. Interdisciplinary groups are also included, and they look after the issues related to captive breeding. Taxon-based specialist groups study their respective domains and analyse the conservation status of the species. Action plans for the effective conservation of species are made to ensure the long-term survival of species.

Source: WCMC, 1992.

Species and Ecosystem conservation

In this approach, the whole area is conserved along with species. This approach is followed for areas with high endemism and a high number of endangered species. Both species and habitat are protected. The flagship species help in conserving many other species inhabiting the area. Umbrella species are species requiring large habitat areas (e.g., elephant, leopard, etc.). The conservation of umbrella species guarantees the protection of other species inhabiting the same area. The giant panda is both a flagship species and an umbrella species.

Integrated landscape conservation

In this conservation approach, a whole landscape or area is conserved. Many habitats are linked in a bigger landscape, and protection of all these proves very useful. The protected areas are present near the adjoining land areas and easily get affected by actions taking place in the region. Both 'reserved' and 'off-reserve' lands act as integrated habitat areas that safeguard biodiversity. Integrated areas may not always function as naturally conserved zones, as human interventions or mixed land use can influence the conservation outcomes. This method is used in cases where species ranges are less, species are sparsely distributed and long-term conservation is not required. It protects the important habitats and coordinates, maintains and restores landscapes with the goal of protection of that area and the adjacent ones.

Mixed approach

Mixed approaches involve a grouping of habitat- and species-based conservation strategies. The conservation approaches should be framed according to the specific ecosystem requirements or species being protected. Habitat, along with species-based conservation methods, can prove useful in attaining protection. For example, conservation of the African elephant (*Loxodonta africana*) involves both habitat protection and maintenance of organisation of individual elephant populations. The African Elephant Action Plan approved by the Convention on International Trade in Endangered Species (CITES) was developed by the African Elephant Specialist Group. It aims to safeguard the survival of elephant populations by both habitat and species conservation methods. The action plan is based on the protection of key habitats and migration corridors and keeping a check on human-elephant conflicts, poaching, and illegal trade in elephant ivory.

The methods followed for biodiversity protection are:

- *In situ* conservation
- *Ex situ* conservation

12.2.1 *Insitu* Conservation

In-situ conservation refers to "on-site conservation". When the species or the communities are protected within their habitat, it is referred to as *in situ* or on-site conservation. It is a method of protecting threatened plant or animal species within their habitat. It involves protection of habitat or the species (from predators). The populations are maintained in their native areas. This is an economical and easy method of biodiversity conservation. This method protects many organisms at a time. The natural habitats help living organisms adapt to different environmental conditions and evolve into a better life form.

National parks, sanctuaries and biosphere reserves are the conserved areas that protect biodiversity under *in situ* conditions. Protected areas conserve species in *in-situ* conditions, i.e., species along with their habitat. The growth and retention of species in their own area is one of the important ways to safeguard biodiversity because the natural evolutionary processes continue and species easily adapt to the surroundings. Wildlife is mainly conserved by this method. The method is successful if the population size is small.

Preserved or protected areas

A protected area is defined as "a well-demarcated geographical area dedicated to long-term conservation of nature with its associated ecosystems which is maintained and managed through legal frameworks.*"* Protected areas include legally designated national and/or international-level conserved areas. They protect nature and cultural heritage and provide a source of livelihood to the local communities. They help in the protection of genetic resources which provide food and medicines and act as a means of recreation and tourism. They work as a shield against disaster and are crucial for securing the long-term delivery of ecosystem services. Protected areas and their associated development can directly benefit communities by providing infrastructure facilities, job openings and other services. The protected area aims to conserve forest ecosystems, prevent loss of biodiversity and secure sustainable ecosystem services. These areas possess a high level of species diversity, threatened species, traditional and wild varieties and genetic diversity.

There are over 2,38,563 areas declared as protected all over the world, which cover around 14.9% of the land area (IUCN, 2018). The 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) recognise protected areas as a main approach for safeguarding biodiversity and for sustainable development. Sustainable development goals (SDG 14, 15 and SDG 3) based on life below water and on land and good health and well-being highlight the role of conserved areas in human welfare, food and water security.

Protected areas are classified with varying levels of protection depending on each country's laws or regulations. IUCN's World Commission on Protected Areas classified protected areas into eight types at the national level and two types at the international level.

Early in the year 1966, the IUCN Commission on National Parks and Protected Areas (CNPPA) with the help of UNEP, UNESCO and the WWF enlisted protected areas. There are ten types of protected areas belonging to three groups.

Group A: Areas of particular interest to the Commission on National Parks and Protected Areas (CNPPA)

These areas are managed by CNPPA. The commission assesses the status of areas and offers technical support as required. These areas covered under this include:

i) Nature Reserves.

ii) National Parks/Provincial Parks.

iii) Natural Monuments/Natural Landmarks

iv) Managed Nature Reserves/Wildlife Sanctuaries.

v) Protected Landscapes

Group B: Areas of interest to IUCN

These areas are found everywhere in the world and of interest to IUCN. The CNPPA also assesses these areas and gives its expertise on those areas especially important from the viewpoint of conservation. The areas under this category include:

vi) Resource Reserves

vii) Anthropological Reserves/Natural Biotic Areas.

viii) Managed Resource Areas.

Group C: Internationally recognised/Affiliated designation

The areas covered in this category include areas which are internationally recognised and have defined links with nature conservation. This also includes areas which have already been designated as protected in any of the prior categories. CNPPA might assess these categories and give importance to these areas in collaboration with other establishments that coordinate with IUCN. These include:

ix) Biosphere Reserves

x) World Heritage Sites (Natural)

Later this classification was rejected due to shortcomings such as no definite definition of a conserved area, description of ten categories by several terms, consideration of a protected area in more than one category and lack of marine dimension. Earlier (1978) CNPPA had described only four classes of the protected areas, but later in the year 1984, the categories of the protected areas were updated, and their number was increased to six.

The IUCN categorised the protected areas into six types depending on land use (Table 12.1). The first five categories represent true protected areas because they focus on the maintenance of biodiversity through environmental conservation. The sixth category refers to managed protected areas to ensure a continuous supply of natural resources. These areas provide protection to larger areas, homes for species, buffers around, and linkages between category I–V protected areas.

According to IUCN, the major categories of protected are:

a) **Strict nature reserve (Category Ia)**: This small area protects biodiversity and geological/geomorphological features by restricting/limiting human intervention (visit and use). This leads to protection of ecosystems, species and/or geodiversity at regional, national or global level.

b) **Wilderness area (Category Ib):** This category includes large, unchanged areas or areas modified to some extent whose natural character and functions are not changed. These mainly include highly protected zones restricted from human intervention. Very few education-related activities and research are allowed. The area safeguards the ecological integrity of the zone and allows native groups to maintain their traditional wilderness-based lifestyle and customs to guarantee their accessibility in the coming times. These areas also protect the cultural and spiritual values and non-material benefits to native or non-native communities.

c) **National Park (Category II):** This category includes large natural zones that are developed to protect biological systems and ecological processes. Restricted activity is allowed for educational, cultural and recreational purposes. Some level of tourism is also allowed for economic contribution. The area is usually large. The main objective behind creating these areas is to protect natural biodiversity and ecological structure, support environmental processes and promote education and recreation. Educational, cultural and recreational activities are permitted to a certain extent so that there is no degradation of natural resources.

d) **Natural monument or feature (Category III):** This small area protects a particular natural monument like a landform, sea mount, geological feature, biodiversity and habitats linked with it. The main aim behind the protection of landscapes or seascapes is to protect traditional, spiritual and cultural values associated with it.

e) **Habitat or species management area (Category IV):** The area protects/restores species or habitats important at national, international or regional levels. The aim behind creating these small areas is the protection of flora or other living assets following conventional management practices. This also conserves habitat areas which are part of a landscape or seascape. These areas promote public education and protection.

f) **Protected landscape or seascape (Category V)**: The areas in which people live in close association with nature. The area possesses natural, biological, cultural and scenic value. This interaction helps in safeguarding and supporting the area along with the values. The area has a large size and sustains a stable interaction of nature and culture via practices of conservation of land and/or sea area. This area aims to do large-scale protection by sustaining species linked with landscapes.

g) **Protected areas in which natural resources are wisely used (category VI):** These areas protect cultural and traditional values associated with ecosystems and habitats. The major activities focus on the integration of sustainable development and nature conservation. Protection and maintenance of cultural landscapes and values are done through traditional practices *via* human-nature interactions. The main objective behind creating these areas is promoting justifiable use of natural resources, keeping in record ecological, economic and social dimensions.

Table 12.1: Categories of protected area.

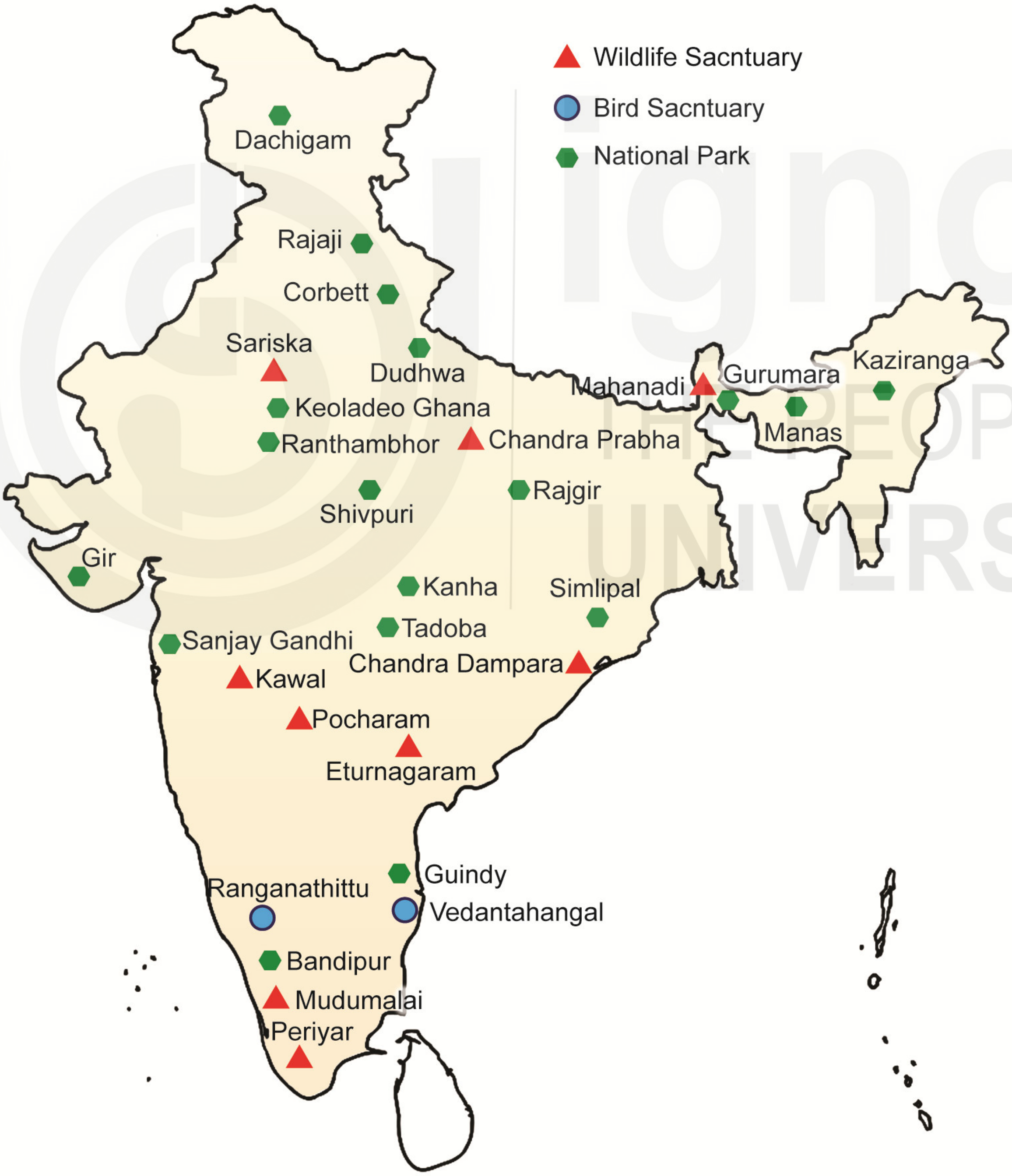
No.	Category	Description
Ia	Strict nature reserve	Developed for biodiversity conservation and act as reference sites for research and monitoring. For example, Urwald Rothwald in Austria.
Ib	Wilderness area	Large unmodified natural areas without human intervention. Managed for protection of ecological integrity. For example, wilderness areas of Sami native region of Finland.
II	National Park	Big areas naturally created for protection of biodiversity and maintenance of ecosystem processes, human activities (spiritual, education, scientific, recreation).
III	National monument of feature	Natural area developed with an aim to conserve cultural and/or natural heritage. For example, Cono de Arita in Argentina.
IV	Habitat/species management area	Area devoted to the protection of a specific species.
V	Protected landscape or seascape	An area of high natural or cultural value formed by people. It safeguards interactions that sustains the area. For example, The Great Barrier Reef in Australia.
VI	Managed-resource protected area	Large areas with low-level, non-industrial, justified utility of natural resources.

Adapted from Dudley, 2008.

World Heritage Sites, biosphere reserves, and Ramsar sites are examples of well-known conserved areas. India has about 998 conserved areas that cover 5.28% of its total geographic area. Conserved areas in India have been categorised into four types according to the Wildlife Protection Act (1972). These are:

1. National Parks
2. Wildlife Sanctuaries
3. Conservation Reserves
4. Community Reserves

India also has biodiversity reserves, **tiger reserves**, elephant reserves and marine protected areas (Fig. 12.1).



▲ Wildlife Sacntuary
● Bird Sacntuary
⬢ National Park
Dachigam
Rajaji
Corbett
Sariska
Dudhwa
Keoladeo Ghana
Ranthambhor
Chandra Prabha
Mahanadi
Gurumara
Kaziranga
Manas
Rajgir
Shivpuri
Gir
Kanha
Simlipal
Sanjay Gandhi
Tadoba
Chandra Dampara
Kawal
Pocharam
Eturnagaram
Ranganathittu
Guindy
Vedantahangal
Bandipur
Mudumalai
Periyar

Fig. 12.1: Important protected areas in India.

These areas are maintained by state and central government. The union government makes the policies and plans for wildlife conservation, while state forest departments implement national policies and plans for the state. The National Board for Wildlife (NBWL), constituted under the Wildlife (Protection) Act, 1972, creates policies and frameworks for safeguarding wildlife in India. This advisory body helps central government in framing policies and taking measures for wildlife conservation in the country. The Board supports protection and growth of wildlife and forests. It assesses all wildlife-related matters and launches programmes near conserved areas. Area covered by protected areas such as national parks and wildlife sanctuaries cannot be changed without the approval of NBWL. NBWL is constituted of 47 members, including the Prime Minister, 19 ex-officio members, three Members of Parliament (two from Lok Sabha and one from Rajya Sabha), five NGOs, and ten eminent ecologists, conservationists, and environmentalists. The chairman of NBWL is the Prime Minister. The National Board for Wildlife follows the recommendations for the development and management of national parks, sanctuaries, and other protected areas. It also decides issues such as limiting activities in those areas (Table 12.2). The State Board for Wildlife assists the state government in deciding any area for its categorisation as a protected area.

Table 12.2: Types of protected areas in India (Jan 2023).

Protected Areas	**No.**	**% of Area Covered**
National Parks (NPs)	106	1.35
Wildlife Sanctuaries (WLSs)	573	3.74
Conservation Reserves (CRs)	115	0.16
Community Reserves	220	0.04
Total Protected Areas (PAs)	1014	5.28

Structure of protected area

Any preserved area needs to possess certain characteristic features such as connectivity, corridors and edge effect. A bigger preserved area indicates the existence of many species. The edge effect is less in round-shaped areas because the perimeter (edge) is less in comparison to the area inside. Corridors are strips of protected land which link reserves. These allow individuals to move freely from reserve to reserve and therefore increase the size of the gene pool and allow for seasonal migration. The fragments get connected, and this permits species to establish and breed among themselves. The connections are also referred to as corridors. Buffer zones are important in any conserved area (Fig. 12.2). Edge effect involves decreasing the circumference-to-area ratio. Edge effects occur at ecotones (where two habitats meet). More species exist at ecotones from different habitats, leading to increased predation and competition. Long thin reserves have a large edge effect, while circular reserves have the least.

A buffer zone is an area that is used to an extent that the core remains unmodified and no human disturbance is allowed. People benefit from this zone, as restricted forestry, farming and other activities are allowed. People work and get money without causing any harm to the species in the core preserve.

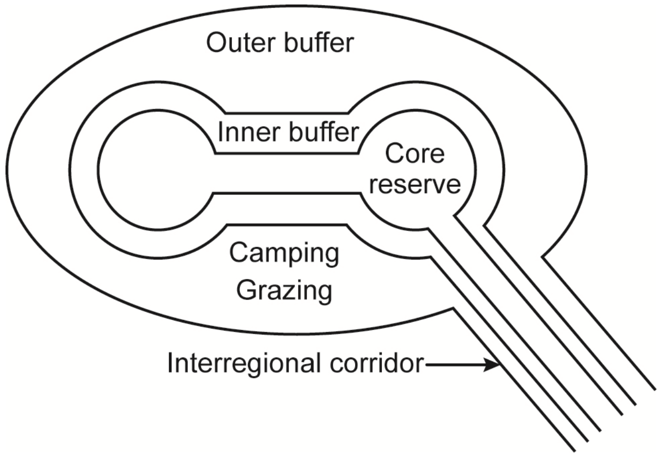


Fig. 12.2: Structure of a preserved area.

i) National Parks

Small reserve areas created to protect wildlife within their natural range. They are declared as protected by the government and isolated from human interference. Grazing and forestry are restricted in these areas. The land area is full of natural beauty. These help in the protection of nature, flora and fauna (Table 12.3). These areas do not get disturbed by human activities but might have been harmed by humans earlier before being declared as protected areas (Box 12.3).

Table 12.3: Goals of Parks, Nature preserves and wilderness.

S. No.	Goals
1	Protection of exceptional geographical and charming beauty of nature
2	Protection of nature on their own
3	Wildlife conservation along with protection of habitat and ecosystem
4	Protection of threatened species and habitats
5	Protection of biodiversity of a zone
6	Maintaining wildlife for hunting
7	Maintaining representative natural areas
8	Aim at recreation and tourism
9	Area maintained for scientific research
10	Formation of corridors and connections between natural areas

Box 12.3: IUCN Definition of National Park.

The International Union for the Conservation of Nature (IUCN) defined a national park as a big area:

a) that are not changed by human activity and where fauna and flora, land forms and habitats provide scientific, educative and recreational information and is a natural beautiful landscape.

b) where the government or authorities of a country take some measures to stop or limit human interference and enforce effective regulations with respect to the maintenance of ecological landforms or aesthetic features, and

c) where visitors are allowed for restricted actions such as recreation.

ii) Wildlife Sanctuaries

Areas created and adopted by the government to protect wild fauna and flora. The actions, including deforestation, utilisation of goods obtained from forests, and agriculture, are not allowed. The first area created under this category was the Vedanthangal Bird Sanctuary near Madras. It was created in 1878. This supported the traditional practices of villagers for protecting birds such as pelicans and herons. One sanctuary was set in Ranganathittu near Mysore in 1942 by the British.

Famous wildlife sanctuaries of India are:

1. Bandipur Wildlife Sanctuary, Karnataka
2. Bhitarkanika Wildlife Sanctuary, Orissa
3. Gibbbon Wildlife Sanctuary, Assam
4. Dachigam Wildlife Sanctuary, Jammu and Kashmir
5. Sunderbans Wildlife Sanctuary, West Bengal
6. Keoladeo Bird Sanctuary, Rajasthan (Now a National Park)
7. Periyar Wildlife Sanctuary, Kerala
8. Mundanthurai Wildlife Sanctuary, Tamil Nadu

iii) Sacred Groves

These are fragments of forest lands of different sizes protected collectively and possessing religious significance (Fig.12.3). Hunting and wood procurement are totally banned in these areas. These areas are not legally protected but are safeguarded by local people and related NGOs. Example: The scrub forest of Rajasthan is owned by the Bishnois community. India has about 14000 to 1,00,000 sacred groves. Hariyali, located in the Chamoli district in Uttarakhand, is the largest sacred grove in India.

Fig. 12.3: Sacred Groove of Meghalaya.

iv) Biosphere Reserves

These are internationally identified areas and have been designated to establish a stable association of humans and the biosphere. They protect nature in specific regions and resolve the issue of protection of biodiversity by switching to justifiable use.

A biosphere reserve is a type of conserved land area in which people are a very important part of the system. The region is categorised into three zones – core, buffer and transition. The core is characterised by an area which is not disturbed or disturbed to a lesser extent. The second zone (buffer) covers the first zone (core) from all sides. In this zone, activities related to research, education and training take place. An area that connects and signifies collaboration between management that maintains the reserve and local people is referred to as a transition zone (Fig. 12.4). The area is created with the aim of biodiversity protection, providing research support, adoption of sustainable economic development, monitoring, education and data acquisition. Nine Reserves of India are a part of the Man and the Biosphere Program of UNESCO.

Major biosphere reserves of India are:

1. Nilgiri, Western Ghats (1986)
2. Nandadevi, Uttrakhand (1988)
3. Nokrek, Meghalaya (1988)
4. Gulf of Mannar, Tamil Nadu (1989)
5. Sunderbans, West Bengal (1989)
6. Manas, Assam (1989)
7. Great Nicobar, Andaman and Nikobar Islands (1989)
8. Simlipal, Odisha (1994)
9. Dibru-Saikhowa, Assam (1997)
10. Dehang-Dibang, Arunachal Pradesh (1998)
11. Panchmarhi, Madhya Pradesh (1999)
12. Khangchendzonga, Sikkim (2000)
13. Agasthyamalai, Western Ghats (2001)
14. Achanakamar-Amarkantak, Madhya Pradesh (2005)
15. Kuchchh, Gujrat (2008)
16. Cold desert, Himachal Pradesh (2009)
17. Seshachalam, Andhra Pradesh (2010)
18. Panna, Madhya Pradesh (2011)

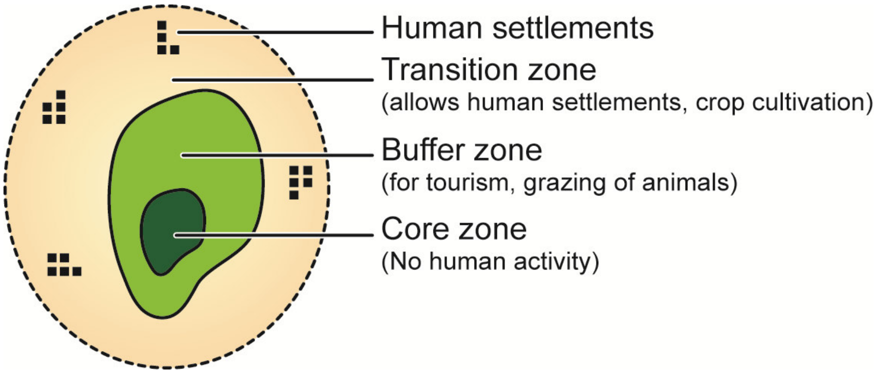

Human settlements
Transition zone
(allows human settlements, crop cultivation)
Buffer zone
(for tourism, grazing of animals)
Core zone
(No human activity)

Fig. 12.4: Diagrammatic representation of various zones of a biosphere reserve.

The biosphere reserve protects all forms of life in their habitat along with the subordinate requirements. It acts as a system for continuous assessment and assessing alterations in the ecosystem. Biosphere reserves safeguard whole ecosystems as compared to a species or habitat. The Biosphere Reserve programme was initially under the guidance of the Man and Biosphere (MAB) programme of UNESCO. This programme aimed to establish and justify the actions for the establishment of many conserved areas.

The concept of designating any area as a biosphere reserve was given in 1979. At present around 714 biosphere reserves are spread in 129 countries of the world. India has 18 biosphere reserves. The Biosphere Reserve Programme of India is guided by the UNESCO MAB programme.

Biosphere reserves aim to:

a) protect ecosystems;

b) ensure long-term protection of biodiversity within their own habitat;

c) promote basic and practical research and continuous assessment;

d) promote management of bioresources;

e) provide support for justifiable growth as required; and

f) promote international co-operation.

A biosphere reserve

- include protected land and coastal areas. They constitute a link connected by objectives of international understanding and sharing of scientific information.
- natural biomes form an important portion of the reserves.
- is area with unusual/unique natural features and rare species
- is large area that protects species in an efficient way and has other utilisation purposes (Fig. 12.5).
- should support research, education and training. They indicate continuing changes occurring in the biosphere.

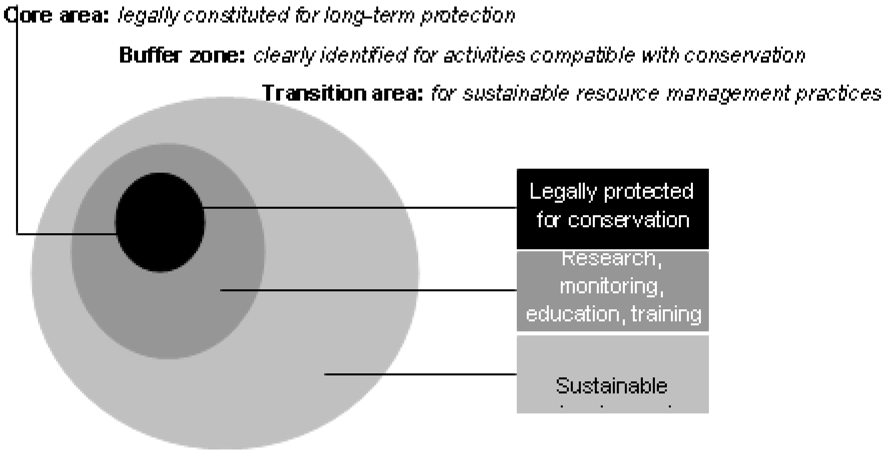

Core area: *legally constituted for long-term protection*
Buffer zone: *clearly identified for activities compatible with conservation*
Transition area: *for sustainable resource management practices*
Legally protected for conservation
Research, monitoring, education, training
Sustainable

Fig.12.5: Various zones in a Biosphere Reserve.

The central government holds responsibility for maintaining these conserved areas. The ways by which they do this are by:

- providing monetary support for the permitted programme
- providing methodical proficiency and training
- issuing guidelines for management and implementation by state government.
- doing strict assessment and supervision

The work of the reserve is guided by the Wildlife Protection Act 1972. An extensive schedule for the improvement and expansion of the network of biosphere reserves was developed. The programme also focused on conserving knowledge and making biosphere reserves more effective.

These areas are formed to protect specific animal species such as tigers and elephants.

Tigers Reserves

The Government of India launched Project Tiger on 1st April 1973 to conserve and maintain a viable number of tigers and their natural surroundings. The project focused on maintaining a feasible tiger population in India. Tiger species are important because of the scientific, cultural and ecological values associated with them. The programme for tiger conservation was initially started in nine tiger reserves established in India. The number of tigers in India at that time was only 268. The main reason for the drastic decline in the wild tiger population was illegal poaching, driven by the demand for tiger body parts in traditional medicine and the illegal wildlife trade, particularly in markets across parts of South and Southeast Asia. Subsequently, after the implementation of “Project Tiger”, the number of reserves was increased to 27. With the establishment of more tiger reserves, the population of tigers increased and reached 3682. Today we have around 58 tiger reserves in India.

The major tiger reserves of India have been listed in Table 12.4.

Table 12.4: Tiger Reserves in India.

S No.	Tiger Reserves in India	State/UT	Year	Total Area (sq km)
1	Bandipur Tiger Reserve	Karnataka	1974	914.02
2	Corbett Tiger Reserve	Uttarakhand	1973	1,288.31
3	Kanha Tiger Reserve	Madhya Pradesh	1974	2,051.79
4	Manas Tiger Reserve	Assam	1973	2,837.10
5	Melghat Tiger Reserve	Maharashtra	1974	2,768.52
6	Palamu Tiger Reserve	Jharkhand	1973	1,129.93
7	Ranthambore Tiger Reserve	Rajasthan	1973	1,411.29

8	Simlipal Tiger Reserve	Odisha	1973	2,750.00
9	Sunderban Tiger Reserve	West Bengal	1984	2,584.89
10	Periyar Tiger Reserve	Kerala	1978	925
11	Sariska Tiger Reserve	Rajasthan	1978	1,213.34
12	Buxa Tiger Reserve	West Bengal	1983	757.9
13	Indravati Tiger Reserve	Chhattisgarh	1982	2,799.07
14	Namdapha Tiger Reserve	Arunachal Pradesh	1983	2,052.82
15	Nagarjunsagar Tiger Reserve	Telangana	1983	3,296.31
16	Dudhwa Tiger Reserve	Uttar Pradesh	1987	2,201.77
17	Kalakad Mundanthurai Tiger Reserve	Tamil Nadu	1988	1,601.54
18	Valmiki Tiger Reserve	Bihar	1990	899.38
19	Pench Tiger Reserve	Madhya Pradesh	1992	1,179.63
20	Tadoba Andhari Tiger Reserve	Maharashtra	1993	1,727.59
21	Bandhavgarh Tiger Reserve	Madhya Pradesh	1993	1,536.93
22	Panna Tiger Reserve	Madhya Pradesh	1994	1,598.10
23	Dampa Tiger Reserve	Mizoram	1994	988
24	Bhadra Tiger Reserve	Karnataka	1998	1,064.29
25	Pench Tiger Reserve	Maharashtra	1999	741.22
26	Pakke Tiger Reserve	Arunachal Pradesh	2002	1,198.45
27	Nameri Tiger Reserve	Assam	1999	464
28	Satpura Tiger Reserve	Madhya Pradesh	1999	2,133.31
29	Anamalai Tiger Reserve	Tamil Nadu	2008	1,479.87
30	Udanti Sitanadi Tiger Reserve	Chhattisgarh	2008	1,842.54
31	Satkosia Tiger Reserve	Odisha	2007	963.87
32	Kaziranga Tiger Reserve	Assam	2007	1,173.58
33	Achanakmar Tiger Reserve	Chhattisgarh	2009	914.02
34	Kali Tiger Reserve	Karnataka	2010	1,097.51
35	Sanjay Dhubri Tiger Reserve	Madhya Pradesh	2011	1,674.50
36	Mudumalai Tiger Reserve	Tamil Nadu	2012	688.59
37	Nagarhole Tiger Reserve	Karnataka	2012	1,205.76
38	Parambikulam Tiger Reserve	Kerala	2010	643.66
49	Sahyadri Tiger Reserve	Maharashtra	2009	1,165.57
40	Biligiri Ranganatha Temple Tiger Reserve	Karnataka	2010	574.82
41	Kawal Tiger Reserve	Telangana	2012	2,015.44

42	Sathyamangalam Tiger Reserve	Tamil Nadu	2013	1,408.40
43	Mukundara Tiger Reserve	Rajasthan	2013	759.99
44	Nawegaon Nagzira Tiger Reserve	Maharashtra	2013	1,894.94
45	Amrabad Tiger Reserve	Telangana	2014	2,611.39
46	Pilibhit Tiger Reserve	Uttar Pradesh	2014	730.25
47	Bor Tiger Reserve	Maharashtra	2014	816.27
48	Rajaji Tiger Reserve	Uttarakhand	2015	1,075.17
49	Orang Tiger Reserve	Assam	2016	492.46
50	Kamlang Tiger Reserve	Arunachal Pradesh	2017	783
51	Srivilliputhur Megamalai Tiger Reserve	Tamil Nadu	2021	1,016.57
52	Ramgarh Tiger Reserve	Rajasthan	2022	1501.8921
53	Guru Ghasidas Tiger Reserve	Chhattisgarh	2023	2,048
54	Veerangana Durgavati Tiger Reserve	Madhya Pradesh	2023	1414.28
55	Dholpur-Karauli Tiger Reserve	Rajasthan	2023	599.64
56	Guru Ghasidas-Tamor Pingla Tiger Reserve	Chhattisgarh	2024	2,829.38
57	Ratapani Tiger Reserve	Madhya Pradesh	2024	1,271.4
58	Madhav Tiger Reserve	Madhya Pradesh	2025	1,751

These reserves were developed on the basis of the ‘core-buffer strategy’. No forestry operations are allowed in the core area. No actions such as the utility of forest services, grazing, or human intervention are allowed within. The buffer zone is considered a ‘multiple-use area’ and provides habitat to the decreasing tiger population in the wild. The collection of non-timber forest produce (NTFP) is permitted to a restricted level in the core zone. It leads to the economic development of nearby villages. The project aimed to

- remove any kind of human interference and exploitation
- manage habitat to rectify any kind of damage caused by humans.
- carefully monitor alterations in fauna and flora.

Another programme named the Tiger Conservation Programme (TCP) for tiger protection was initiated by WWF in 1997. It aimed at long-term protection of this magnificent species and preventing its extinction (Fig. 12.6). The programme strengthened management and continuous assessment of tiger habitat and focused on public awareness and provision of financial support and international cooperation for tiger conservation. WWF helped in the restoration of tiger habitats and maintaining the corridors, which eventually led to an increase in tiger populations. It also helped in areas such as research and monitoring, raising public awareness and mitigation of tiger-human conflicts.

Radio telemetry is a technique in which a radiometer is tied to the collar area of tiger to study its activities.

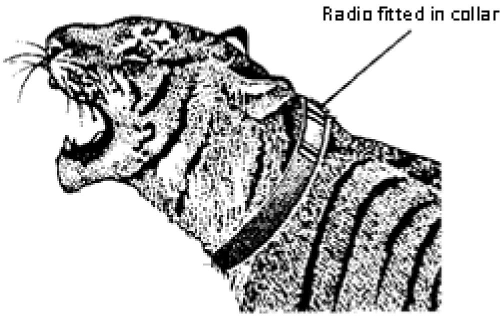


Fig. 12.6: Radio telemetry.

Elephant Reserves

Asian elephants inhabit areas ranging from forests to grasslands. The fragmentation of forest areas due to numerous human activities (construction of dams, railway tracks, agriculture) and conversion of forests to human settlements. These lead to a drastic reduction in elephant population.

A major step towards the protection of Asian elephants was the beginning of Project Elephant. The project started in the year 1992. The recommendations given by the task taskforce of the Ministry of Environment, Forests and Climate Change guided the project (Fig. 12.7). The project aimed at maintaining a high number of elephants by safeguarding their survival in their natural habitats. The project also facilitated the provision of monetary and technical assistance to states having huge numbers of wild elephants. Another purpose behind the project was the reestablishment and maintenance of areas inhabited naturally and common paths taken by animals for migration. Another focus was the implementation of a scientific plan for the organisation and protection of elephant habitats and their viable populations. Measures focusing on minimising human-elephant conflicts were also initiated. The project is running in various states having a good number of elephants, including Andhra Pradesh, Arunachal Pradesh, Assam, Jharkhand, Karnataka, Kerala, Meghalaya, Nagaland, Orissa, Tamil Nadu, Uttaranchal and West Bengal.

Fig. 12.7: Asian Elephant.

Activities imitated under Project Elephant are:

- protection, restoration and improvement in natural habitats of elephants;
- connecting the split habitats by creating corridors;

- connecting paths taken by elephants for their activity from one forest to another;
- safeguarding elephants from poaching;
- implementing steps for conservation of wild species;
- managing captive elephant populations;
- developing scientific techniques for safeguarding zones inhabited by elephants and maintaining them in huge numbers in India; and
- mitigation of issues related to man-elephant conflict.

Effective steps for conservation of elephant species can be taken if information related to their genetic makeup, behaviour, eating and breeding habits is known. Wildlife Institute of India (WII), Bombay; Natural History Society (BNHS); Centre for Ecological Sciences (CES); and Asian Elephant Research and Conservation Centre, Bangalore, are research organisations working on knowing the animal behaviour and assisting in the management of elephant populations.

Crocodile Conservation

The project related to the breeding and management of crocodiles was initiated by the government in 1976. The project primarily focused on saving the endangered Indian crocodile, freshwater and marine species and gharial. Breeding was done at centres established in different areas of the country, followed by their release in the natural habitats. Several sanctuaries, especially Chambal Sanctuary in Madhya Pradesh, have been designated only for crocodile protection.

In situ conservation programmes related to the protection of animals such as Indian rhinos, lions, primates and marine animals such as dolphins were initiated. An Indo-British joint programme aiming at breeding and protection of the threatened white-winged wood duck followed by its release in conserved zones of the Northeastern region was also undertaken.

v) Wetlands

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention, 1971).

Wetlands act as habitats for plants and animals. They support many rare or endangered species. Shallow water of wetlands provides an appropriate environment for rearing and breeding of water birds such as waterfowl. Wetlands also provide support to fish species and many animals. Coastal wetlands act as ecotones between aquatic and land habitats and support various species.

In India, they are found in variable habitats ranging from cold areas of Ladakh, wet humid areas of Imphal, warm areas of Rajasthan, tropical regions and wet humid areas of the southern peninsula (Fig. 12.8). In India, about 4 million hectares of area are occupied by wetlands (both natural and manmade).

Fig.12.8: Wetland.

Maintenance of water regime, filtering of pollutants, circulation and replenishment of nutrients are the main functions of wetlands. They control floods, recharge aquifers, minimise run-off from the surface areas, control erosion and improve water quality. Wetlands treat wastewater and capture the nutrients effectively through fisheries and agriculture.

Coastal wetlands possess unique vegetation called mangroves (Fig. 12.9). Mangroves act as barriers and protect their riparian region, including many villages, from storms arising from the Bay of Bengal.

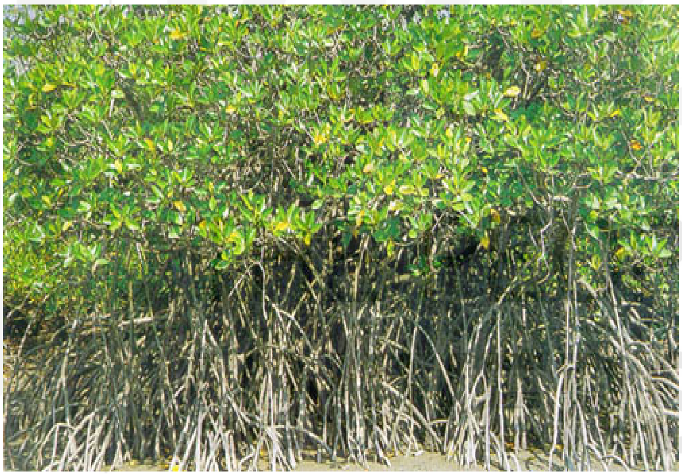


Fig. 12.9: Mangroves.

Natural wetlands are linked to rivers. Various multipurpose projects that harness river water also increase the wetland areas. Example – Bhakra Nangal Dam in Punjab. Some natural and man-made lakes also act as wetlands and support a number of bird and animal species. For example, Chilka Lake, Sukhna Lake, etc.

Wetland areas have three different zones:

- activity zones present at periphery
- buffer zone
- conservation zone that represents the core

Mangroves cover about 6,740 square kilometres of area in India. Sundarbans is the largest area occupied by mangroves. The states of Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, Goa and the Andaman and Nicobar Islands also have many wetland areas.

The Ramsar Convention of 1971 was the first global meeting for the protection of wetlands. The important wetland areas were listed in this convention. Chilka and Bharatpur are the wetlands listed first from India. A National Wetland Management Committee was constituted by the government for the conservation and organisation of these ecologically peculiar zones so that pisciculture, aquaculture and research studies can be promoted. World Conservation strategy was framed for

- running of important ecological processes,
- protection of biodiversity,
- justifiable use of species and
- implementing methodologies and issuing preventive environmental rules for the three above-listed goals.

World Heritage sites

UNESCO has designated specific global areas, irrespective of desert, forest, mountain range, lake, monuments, etc., as world heritage sites. This declaration was done in the convention organised by UNESCO in 1972 in the context of conservation of culture and natural heritage. The names of sites of immense importance from the perspective of cultural importance and part of tradition were listed. A fund called the World Heritage Fund was formed for the protection and maintenance of these sites. Many cultural (563), natural (144), and mixed (23) sites from around 125 countries have been listed in the Convention. All these sites seek protection through joint efforts and support of all the member nations. This Convention was approved by 174 countries. India signed the agreement in 1977. According to recent reports, India has 43 UNESCO World Heritage Sites, which include 35 cultural, 7 natural, and 1 mixed (Fig. 12.10). These sites showcase India's rich cultural, historical, and ecological diversity.

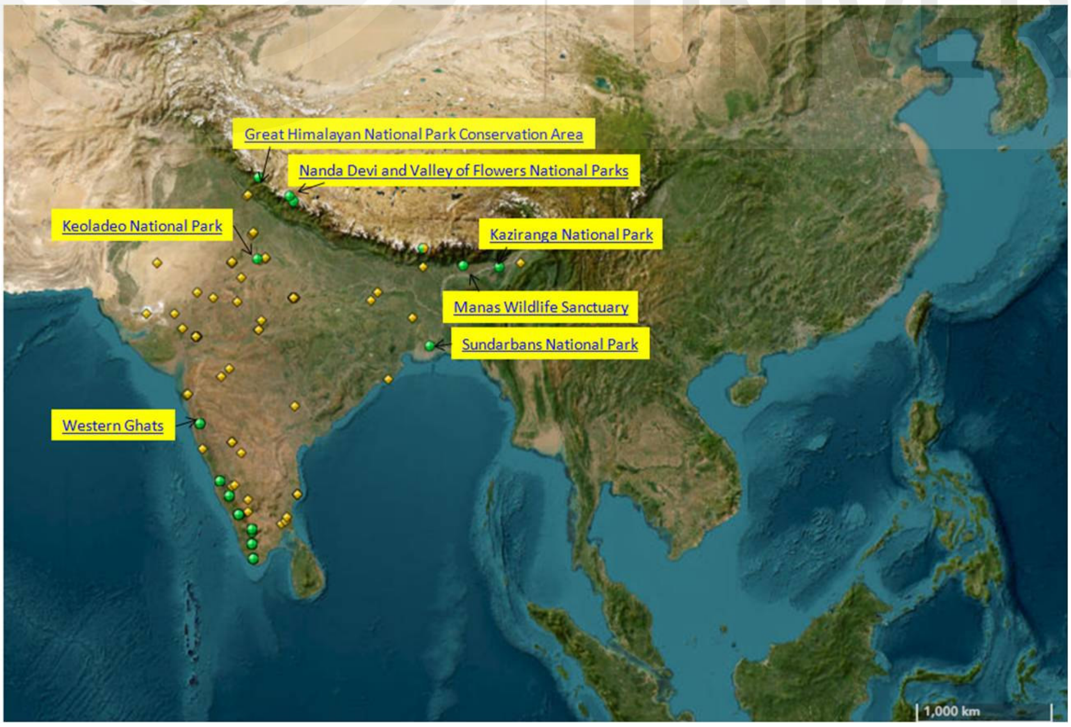

Great Himalayan National Park Conservation Area
Nanda Devi and Valley of Flowers National Parks
Keoladeo National Park
Kaziranga National Park
Manas Wildlife Sanctuary
Sundarbans National Park
Western Ghats
1,000 km

Fig.12.10: Map showing UNESCO World Heritage sites including natural sites in India.

Seven natural heritage sites of India include:

1. Great Himalayan National Park Conservation Area (2014)
2. Kaziranga National Park (1985)
3. Keoladeo National Park (1985) (Fig. 12.11)
4. Manas Wildlife Sanctuary (1985)
5. Nanda Devi and Valley of Flowers National Parks (1988, 2005)
6. Sundarbans National Park (1987)
7. Western Ghats (2012)

Fig.12.11: Keoladeo Ghana National Park.

SAQ 1

a) State whether the following statements are 'True' or 'False':

   i) Unique genetic features of a species or a population represent species diversity.

   ii) Large, unmodified or slightly modified areas whose natural character and functions are not changed by humans are called wilderness areas.

   iii) Ecosystem diversity is a complex network of various types of ecosystems and dynamic interactions between them.

   iv) High genetic diversity reflects less adaptability of a species to its habitat and changing conditions.

   v) National Board for Wildlife makes recommendations for the declaration and administration of protected areas.

b) Write the full form of the abbreviations.

   i) NBWL

   ii) IUCN

   iii) CNPPA

   iv) SDG

12.2.2 *Ex situ* Conservation

This process is also known as "**off-site conservation".** In this process species are taken out from their natural habitat or ecological zone and maintained under artificial conditions. It is done to protect the species and prevent it from getting endangered. It is used for conservation of wild and cultivated species as well as genetic resources. This type of conservation utilises a wide range of techniques and facilities. *Ex-situ* conservation can be done in various ways:

- establishing gene banks, where sperm, ova, and seeds are stored at controlled temperatures and humidity.
- zoos and botanical gardens.
- microbial culture and *in vitro* plant tissue
- artificial propagation of plants and captive breeding of animals, with the option of reintroducing them back into their own habitat.

The evolution and adaptation capacity of the species gets affected if it is maintained in an unnatural habitat. The maintenance of species under ex-*situ* conditions is expensive. Cryogenic storage is not economically feasible. In cryogenic storage, the conserved specimens show adaptability issues when taken back to their natural habitat. Species also are not able to adapt to changing habitat or conditions. Seed banks do not prove effective for plant species that possess seeds which lose their fertility with time. Living organisms maintained in *ex-situ* conditions do not show immunity and resistance to diseases and pests. All the physical conditions, along with the urge for particular ecological conditions, make this type of conservation difficult for endangered species.

Ex-situ conservation might involve some old, conventional conservation methods or new laboratory methods. The main limitations in adopting this conservation strategy include adaptability issues, genetic variability, lack of space, restricted number of animals and surplus fund availability. Research studies related to the basic biology, behaviour, and habits of the species kept in captivity can suggest the ways how the conservation should be done with a scope of improvement.

In vivo methods

About 1500 botanic gardens present throughout the world maintain more than three million accessions.

i) Botanical Garden

The list of threatened plant species is increasing due to factors such as overexploitation, pollution, climatic change, etc. This has led to finding ways for the protection of plants before many of them get extinct. Plants are a valuable resource; hence, there is an urgent requirement for their conservation. Botanic gardens protect and conserve rare and threatened plant species (Fig. 12.12, 12.13). Many species of endangered plants are preserved in botanic gardens (Box 12.4). These gardens provide information related to the conservation of wild species and horticultural and crop plants outside their habitat.

Botanical gardens

- acclimatise many native and vulnerable species
- plant species are restored along with their habitats
- commercial use of plant species available at large scale
- provide education to students and people residing near wildlife areas.

At present India have 34 botanic gardens.

Botanic Gardens Conservation International (BGCI) was established by IUCN in 1987. This organisation developed a plan for strengthening the role of botanical gardens in the protection of plant species in the year 1989. It linked about 400 botanic gardens working on plant conservation present throughout the world. Botanic gardens are part of BGCI. They are running many conservation programmes. These include:

- National Botanical Research Institute, Lucknow, Uttar Pradesh
- Botanical Garden Guru Nanak Dev, Amritsar, Punjab
- Institute of Forest Genetics & Tree Breeding, Coimbatore, Tamil Nadu
- Narayana Gurukula Botanical Sanctuary, North Wayanad, Kerala
- Botanical Garden “Dr. H.S. Gour Vishwavidyala”. Sagar, Madhya Pradesh
- Tropical Botanical Garden and Research Institute, Pacha-Palode, Trivandrum, Kerala
- Zoo Outreach Organisation/Captive Breeding Specialist Group (C.B.S.G.), Coimbatore, Tamil Nadu
- Magali Estates (P) Ltd., Padagiri, Kerala.

A scheme with the title “Assistance to Botanic Gardens” supported botanic gardens and offered assistance in the implementation of *ex-situ* conservation methods for threatened flora in their own regions.

Fig.12.12: Botanical Garden located at Howrah.

Box 12.4: Royal Botanic Garden in Kolkata.

The Royal Botanic Garden (Indian Botanic Garden), Kolkata, was established by the East India Company in 1787. It is considered one of the biggest botanic gardens found throughout the world. It holds a vast herbarium and maintains native flora from different areas of the country. Garden has established extensive plantations of orchids, bamboos, and palms. It shared plants with Kew Botanic Gardens and other European gardens. It serves as the main centre of research related to plants (Fig. 12.12). Plants kept in this garden were listed in 1830 and named 'The Alphabetical Index'. The names of the plants were listed in fourteen languages, including Arabic, Oriya and Latin binomial names.

Fig.12.13: The great banyan tree in botanical garden, Kolkata.

ii) Zoological Garden

The areas in which species are maintained in captive conditions are called 'zoos' or 'zoological parks/gardens'. In zoos, animal species are protected outside their habitat conditions. Besides conservation, they are also important centres for education related to the environment and research. Zoos have been created since ancient times (about 200 years ago). The zoological parks were established in many parts of the world. Aquaria, bird parks and safari parks are areas in which species are protected outside their habitats.

The World Zoo Conservation Strategy defines zoos as areas involved in wildlife protection. Zoos act as the areas where many threatened animal species are saved (Box 12.5). In the last decade, management programs for the upgradation of zoos have been developed.

Box 12.5: World Conservation Strategy.

The World Conservation Strategy is an international document related to the conservation of living resources. Information procured from governments, non-governmental organisations such as the United Nations Environment Programme (UNEP), the World Wildlife Fund (WWF), the Food and Agriculture Organisation of the United Nations (FAO) and other experts is included in this document. It was prepared by the International Union for Conservation of Nature and Natural Resources (IUCN) in 1980. According to the World Conservation Strategy, the goals can be achieved only when zoo authorities take three major initiatives by:

- giving support for protection of threatened species and associated ecosystems.

- providing support for developing knowledge to achieve conservation.
- promoting awareness required for conservation, attaining sustainability for use of resources resulting in equilibrium between humans and environment.

Central Zoo Authority (CZA) was formed under section 35 of Wild life (Protection) Act (1972) in 1992. All the zoos need to get recognition from CZA for their functioning. CZA ensures that for

Animals kept in zoos should have suitable conditions for maintaining their psychological and physical health. Multiplication and an increase in the declining population for species in the wild can be done in the zoo. Domestication can be reduced if zoo populations are maintained following the strict guidelines. Properly maintained and managed animal populations represent a valuable genetic reservoir for the survival of species. Breeding programmes/practices are followed. About 300 threatened species are maintained by regional breeding programmes. The World Zoo Conservation Strategy has emphasised the need for more programmes related to animal protection.

Arboreta: These refer to botanical gardens that maintain tree species.

Nurseries: Places where plants are raised up to the seedling stage.

Field gene banks: Places where plant genotypes are conserved. The plant genetic resources can easily be obtained. The plants require a high level of maintenance, monetary input, space and techniques for safeguarding from natural calamities, pests and pathogens. Central Rice Research Institute in Orissa has conserved about 42,000 rice varieties.

Captive breeding: Animals are bred in captivity and reintroduced in the wild.

In-vitro techniques

These include various laboratory practices adopted for achieving conservation of plant/animal/microbial diversity. These include germplasm banks, tissue culture techniques, cryopreservation, artificial seeds and cloning methods.

i) Germplasm banks

The places where germplasm or material is conserved under controlled conditions are called germplasm or gene banks. These are also known as seed banks or DNA banks depending on the material conserved. Seeds of plants and sperm and ova of animals are stored here. The germplasm of fauna and flora species can be well-preserved in a small space along with their scientific identity. They guarantee the right use of material, equal sharing of benefit by all nations, and facilitate sharing of knowledge.

Three types of materials are protected in these banks. These are:

- Base collection: materials that require long-term storage and are not used on a routine basis.
- Active collection: materials kept for a specific period and used later as per requirement
- Working collection: Samples used by breeders or researchers for research purposes and crop improvement.

ii) Seed banks

The areas where the seeds are stored for long-term protection are called seed banks. The genetic diversity is stored for a long time if seeds obtained from different varieties of plants are stored. Seeds are small; therefore, they can be maintained and handled easily and can be used for a long time. The seeds are kept at a temperature of -10 to -20℃. Silica gel is put in the containers used for storage of seeds to remove humidity. The seeds remain viable because of the low temperature. The method is easy, as it requires less space, no labour for storage of many samples, and cost-effectiveness (Fig. 12.14).

Orthodox seeds (which remain viable for a longer duration) can be maintained in seed banks. These seeds get dried at low humidity and kept at low temperatures. The seed banks do not work well for seeds which do not remain viable for long (in dry and freezing conditions) (recalcitrant seeds). The seeds are collected and are followed by drying to get moisture content below 6%. The seeds are stored at a very low temperature (below -18℃). Continuous monitoring has to be done to check the viability and regeneration ability of seeds.

Fig. 12.14: Seed bank.

Seed Bank projects

The Royal Botanic Gardens, Kew, manages the world’s largest seed bank initiative known as the Millennium Seed Bank (MSB) Project. Since its launch in 2000, the MSB has become the most extensive and diverse genetic repository of wild plant species globally due to the contributions from over 100 countries. While seed collections are preserved in their country of origin, a portion is also sent to the MSB as a safety backup.

Kew holds more than 8.5 million items, making it home to the most comprehensive and diverse botanical and mycological collections in the world. These collections represent about 95% of vascular plant genera and 60% of all known fungal genera. The MSB’s seed collection alone comprises over 2.4 billion seeds, representing nearly 40,000 different wild plant species, making it the most diverse of its kind.

Kew's DNA and Tissue Bank, established in 1992, currently stores around 48,000 samples of plant genomic DNA at -80℃ and over 12,000 silica-dried tissue samples at room temperature, covering approximately 35,000 plant species. Additionally, its in vitro collection includes around 6,000 cultured specimens of plants and fungi, such as orchids and both mycorrhizal and non-mycorrhizal fungi.

National Bureau of Plant Genetic Resources (NBPGR)

The National Bureau of Plant Genetic Resources (NBPGR) plays an important role in managing plant genetic resources (PGR) at the national level in India. This institute has organised its functions into five specialised divisions: Plant Exploration and Collection, Germplasm Evaluation, Germplasm Conservation, Plant Quarantine, and Genomic Resources. The Division of Germplasm Conservation (DGC) oversees the National Genebank (NGB) of India, which is tasked with the *ex-situ* conservation of germplasm. This includes preserving genetic material in various forms such as seeds, vegetative propagules, tissue and cell cultures, embryos, and gametes.

Over the past forty years, the NGB has expanded significantly, evolving into one of the world's largest seed vaults and supporting crop improvement initiatives across nearly all agricultural and horticultural crops that are maintained by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi. Through strong partnerships within the National Agricultural Research System (NARS), the NGB has actively gathered, acquired, and assembled valuable germplasm from a wide range of crop species. As a result of these collective efforts, the base collection now contains over 460,000 accessions from more than 1,800 species, making it the second-largest genebank globally.

As of April 2024, the seed genebank houses 469,380 accessions from 2,150 species (Table 12.5). Additionally, the *in vitro* genebank preserves 1,985 accessions as meristem cultures, while the cryogenebank stores 12,790 accessions in the form of seeds, dormant buds, and pollen (Table 12.5).

Table 12.5: Seed Genebank Status in National Gene bank (as of April, 2024)

Crop Groups	No. of accessions
Seed genebank	
Cereals	177205
Millets	60435
Forages	7522
Pseudocereals	8221
Legumes	68881
Oilseeds	63508
Fiber Crops	63508
Vegetables	29504
Fruits and Nuts	302
Medicinal & Aromatic Plants	9530
Ornamental	743
Spices & Condiments and Flavour	3697
Agro-forestry	1710
Duplicate Safety Samples	10235

Trial Material (Wheat, Barley)	10771
Total	**469320**
***In vitro* genebank**	
Tropical fruits	449
Temperate and minor tropical fruits	390
Tuber crops	527
Bulbous crops	178
Medicinal & aromatic plants	211
Spices and industrial crops	230
Total	**1,985**
Cryobank	
Recalcitrant and Intermediate	7,784
Orthodox	3,962
Dormant bud	389
Pollen	655
Total	**12790**

National Bureau of Fish Genetic Resources (NBFGR)

Conservation of fish germplasm is required for increasing fish production. A plan for conserving biodiversity was formulated under the Convention on Biological Diversity. The National Bureau of Fish Genetic Resources (NBFGR), established in 1983, has been focused on making continuous efforts to maintain fish populations in India. The thrust areas of the bureau are:

- development of a database on fish biodiversity in India.
- creating an inventory of fish species
- development of fish habitat restoration programmes
- development of aquatic sanctuaries
- DNA fingerprinting of fish species
- use of genetic markers in fish conservation
- cryopreservation of gametes, embryos and DNA materials.
- maintaining a database of exotic species and quarantine.
- issuing guidelines for the introduction of exotics and quarantine.

The database related to fish diversity of India has been developed by the institute. It contains information related to the systematics, habitat and distribution of 2118 finfish. Karyotypes and isozyme profiles of fishes have also been included. Specific information on fishes according to ecosystem and status of species (threatened or rare, etc.) can be obtained from this database. About 79 threatened fish species of India have been listed.

National Bureau of Animal Genetic Resources (NBAGR)

Different varieties of livestock from different regions of the country are maintained. They have been grown in areas having different climatic conditions and soil. The animal resources mainly include animals such as cattle, buffaloes, goats, sheep, swine, equines, camels and poultry. Yak, geese, ducks, quails and pet animals also come under the category of animal resources. Most of these breeds are unique due to their adaptation to the agro-climatic conditions of their habitat. The Bureau was established in 1984 and created a database on indigenous farm livestock genetic resources. The database is continuously upgraded. The Bureau is involved in the characterisation and evaluation of livestock genetic resources of India with the joint efforts of State Agricultural Universities and ICAR institutes. The Bureau gives reports of various animal breeds to the government and other agencies working in the field of biodiversity conservation.

iii) Tissue culture

Plant tissue culture is an *in vitro* technique in which a cell, tissue and organ are cultured in synthetic medium under controlled environmental conditions. It depends on the totipotency of plant cells. Totipotency is the capacity of a cell to produce a new plant. This technique helps in raising plants in large numbers. Selected varieties and threatened species can be protected using this technique. Mature cells become meristematic after dedifferentiation followed by redifferentiation to produce a new individual. The protoplasts, cells, tissues and organs can generate new plants. Tissue culture technique proves useful in regenerating valuable endangered species. Large-scale propagation of germplasm can result in the production of multiple copies of plants (Fig. 12.15). The numbers of *Leptadenia reticulata* (Jeewanti), an endangered medicinal plant, are increased by raising many plants using leaf as an explant. Somaclonal variations and/or loss of capacity to show morphological growth limit the micropropagation by tissue culture. Tropical species such as cacao, coconut, *Citrus* spp., coffee, etc., have been successfully conserved through tissue culture techniques.

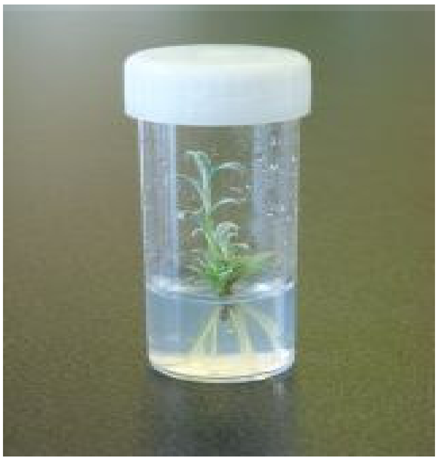


Fig.12.15: Propagating plant through tissue culture.

Institutes working for biodiversity protection at the national level

Institutes such as NBPGR, NBFGR and NBAGR play an important part in safeguarding biodiversity in *in-situ conditions*.

National Bureau of Plant Genetic Resources (NBPGR)

The National Bureau of Plant Genetic Resources (NBPGR) was set up in 1977. The institute works in the area of crop improvement through germplasm collection. The Bureau maintains base collections of crop species by storing them at -20ºC in the gene banks. It has several regional stations that maintain field collections. It also helped in cryopreservation of seeds, pollen and *in vitro* cultures in liquid nitrogen (-196℃). Bureau also aims to improve the quality and effectiveness of many other services associated with the justifiable use and management of plant resources**.**

The major objectives of NBPGR are:

To act as the nodal institute at a national level for acquisition, management and genomics-based profiling of indigenous and exotic plant genetic resources (PGR) for food and agriculture and to carry out related research and human resources development for sustainable growth of agriculture.

- To plan, organise, conduct and coordinate exploration and collection of indigenous and exotic plant genetic resources.
- To undertake the introduction, exchange and quarantine of plant genetic resources.
- To characterise, evaluate, document and conserve crop genetic resources and promote their use, in collaboration with other national organisations.
- To develop an information network on plant genetic resources.
- To conduct research, undertake teaching and training, develop guidelines and create public awareness on plant genetic resources.

iv) Cryopreservation

Cryopreservation (freeze preservation) is a process in which germplasm is preserved by storing it at very low temperature conditions (-196℃). The cryopreservation of a sample brings the culture to a condition where no division or metabolism takes place and biological activity stops. In plants, tissues and seeds are preserved, while in animal cells, spermatozoa, ovarian or embryonic tissues and embryos are conserved via cryopreservation. Eggs, sperm, embryos and plant tissues are collected and preserved to conserve species and use in future breeding.

v) Artificial seeds

Embryos obtained from somatic cells can be cultured to get plants under *in vitro* conditions. The process is called embryogenesis. These embryos are subjected to dehydration and covered with gels formed by chemicals such as sodium alginate, calcium alginate, and polyacrylamide to prevent desiccation. These are artificial or synthetic seeds. Shoot tips and nodal segments of *Mentha arvensis,* a highly medicinal plant, have been encapsulated by using sodium alginate beads and stored for conservation.

vi) DNA clones

DNA, the hereditary material of a cell, can be protected, and this is done by cloning DNA segments into vectors such as cosmids, plasmids and bacteriophages and storing them for a long time. A small number of samples obtained from threatened and rare species can easily be conserved by this method. The small amount of DNA can be increased by gene cloning methods to get a significant amount of DNA.

Techniques for *ex-situ* conservation

i) Captive breeding

In this method, an animal species is removed from its habitat and maintained in artificial conditions. It acts as an important strategy for saving threatened wild species whose number is declining very fast. The wild population is kept in captivity for increasing the population (number). The animals later are again established in the population found in their native/wild areas. Selective breeding and re-introduction are the major mechanisms of captive breeding. The response of species might vary in captive breeding. Some species might not adapt to the conditions under captivity and do not mate. Techniques such as artificial insemination and embryo transfer prove useful for increasing the population in these cases. The technique is expensive, as it requires huge infrastructure and facilities. Giant pandas, cheetahs, elephants, penguins, hummingbirds, and killer whales show issues in breeding.

ii) Embryo storage and transfer technology

The embryo is stored and later on transferred via artificial insemination to get the progeny. This technique is useful for raising laboratory animals, farm animals and endangered species. Fertilised eggs or young embryos (about the 8-cell stage) are taken out from the reproductive tract of a donor female and introduced into a surrogate mother that carries embryos till the time a young one is produced. The donor and recipient are of different species but belong to the same genus.

In the superovulation technique, the donor is treated with hormones involved in increasing fertility (such as follicle-stimulating hormone that stimulates the release of eggs). Eggs get fertilised and transferred to surrogate mothers. This method has worked very well in cattle. Embryo bisecting is done to get identical twins or triplets in sheep.

iii) Artificial insemination

Sperm is frozen and later transferred to another breeding centre. Sperm fertilises with eggs. The method proved very effective for animals such as cats, elephants and cheetahs.

iv) Somatic cell cloning

Somatic cell cloning is a technique that aims at increasing the number of animals from species that are likely to get extinct (Fig. 12.16). The technique proved useful in sheep at the Roslin Institute in Edinburgh. A rare breed of cattle having only one old female and some sperm was saved using the technique. Somatic cells of the ovary were taken from the lady and fused with eggs without nuclei obtained from another breed. The fertilised eggs were placed in an Angus cow (a common breed), and the calf produced had the same identity as the lady.

Cloning proved useful in recovering extinct species. Intact nuclei from 20,000-year-old carcasses of woolly mammoths found in the permafrost were recovered in Siberia. The nuclei were introduced in elephant eggs, and nucleated eggs or fertilised eggs (embryos) were transplanted into surrogate mothers. The calf produced is a true woolly mammoth.

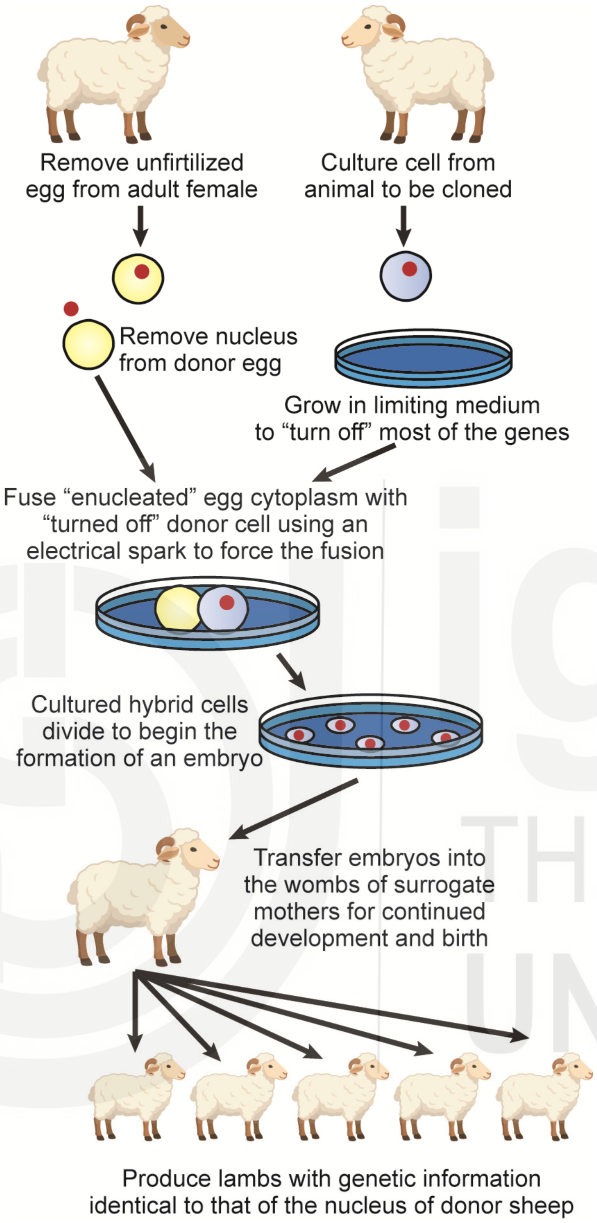

Remove unfirtilized egg from adult female
Culture cell from animal to be cloned
Remove nucleus from donor egg
Grow in limiting medium to "turn off" most of the genes
Fuse "enucleated" egg cytoplasm with "turned off" donor cell using an electrical spark to force the fusion
Cultured hybrid cells divide to begin the formation of an embryo
Transfer embryos into the wombs of surrogate mothers for continued development and birth
Produce lambs with genetic information identical to that of the nucleus of donor sheep

Fig.12.16: Steps involved in technique of somatic cell cloning.

v) Fostering

Animals produce many eggs but rear few of them. Extra eggs can be collected and hatched later. The animals captured and maintained can be reared using a foster parent. The technique helped in rearing and maintaining bird species. The young animals behave differently in wild and captive conditions. Animals bred in captive conditions develop close bonds with humans as compared to members of their own species.

Reintroduction of species raised under captive conditions proves beneficial in natural ecosystems. Various points, such as the behaviour of animals, pathogens and parasites in natural systems, and the mingling of subspecies, restrict the transfer of species to natural areas. Space, finances, and facilities are the basic requirements for the success of a project related to captive breeding. Reintroduction has proved useful for about 120 species.

vi) Translocations

Translocation involves transfer of species from their own habitat or captivity to different habitat. The process involves introductions or reintroductions. Translocation has been successfully done for about 700 species each year. These processes are supported by international captive breeding programmes.

vii) Introduction

The process involves movement of species from their natural zone or captivity into an outside area. Such species are present in a particular area. Information related to habitat and behaviour is required to ensure their better adaptability to the habitat.

viii) Reintroduction

This process involves the transfer of a species from the outside region or captivity to its original area. The process needs careful observation. Habitat, behaviour and social arrangement of the species that are reintroduced should be studied. For example, one-horned rhino is restricted to Dudwa forests. The poaching and killing of the species led to a huge loss of the animal species from the region by the end of the 19th century. The species was raised under captive breeding and reintroduced in Dudwa in 1984.

SAQ 2

a) Answer the following in one word:

   i) Species that are charismatic, recognised, popular, and selected to appeal to the public and thereby help to protect other species in an area.

   ii) The conservation approach that ensures the protection of areas required for survival and sustenance.

   iii) The protection of this species safeguards the existence of other species present in the same habitat.

   iv) The seeds that lose fertility over a long period of time.

   v) The strips of protected land which link reserves.

   vi) Botanical gardens maintaining tree species.

b) Fill in the blanks.

   i) In a preserved area, more species exist at ……………………. from different habitats, leading to increased predation and competition.

   ii) A ……………………. moderately used land without human intervention and transformed into a natural area in the inner zone.

   iii) ……………………. are the patches of protected forests of varying sizes and having religious importance.

iv) Chilika Lake in Orissa is a …………………… .

v) Coastal wetlands possess unique vegetation called ……………. .

vi) Sunderbans is an area famous for their …………………….. .

c) State whether the following statements are 'True' or 'False'.

i) Botanical gardens aim to safeguard biodiversity within the habitat.

ii) The Royal Botanic Garden, Kolkata is the oldest botanical garden found in the world.

iii) The National Bureau of Animal Genetic Resources has created a list of native livestock resources found at the farm.

iv) Cryopreservation technique cannot be adapted for orthodox seeds.

v) National Bureau of Plant Genetic Resources (NBPGR) maintains the germplasm of crop species for long-term storage.

vi) Reintroduction means transfer of entities from their natural areas or detention to a new area of inhabitance.

12.2.3 Traditional Ecological Knowledge in Biodiversity Conservation

Traditional Ecological Knowledge (TEK) is a kind of knowledge and beliefs transmitted through oral tradition and first-hand observation about the relationship of living beings (including humans) with one another and with their environment (Berkes, 100). It is a valuable information system that helps in protecting natural resources. This information considers the associations between the living organisms and their surroundings that are being transferred through generations. The knowledge bears its relevance for the protection and justifiable utility of biological resources. It emphasises traditional cultural practices. TEK includes knowledge about various areas such as ecosystem management, medicine, pharmacology, agro-areas, wildlife, and fisheries. The conventional knowledge about living organisms, soil and land forms for the justifiable use of resources, their management by different techniques and practices, coordination and cooperation, and implementation of laws and policies are major issues of TEK. This knowledge is transferred from one generation to another.

Indigenous peoples possess good knowledge about ecological systems and are engaged in biodiversity conservation. These people know about various uses of biodiversity. Despite various efforts made by the scientific communities, TEK has not been saved to the extent required and is getting lost. This is because the information is not acknowledged and ignored.

Traditional knowledge is a vital component of biodiversity protection. Systems of medicine, i.e., Ayurveda, Siddha, and Unani, are part of the healthcare system in India. These systems rely on the use of biological resources. Local communities have contributed to the protection of native areas, as they have been considered sacred and worshipped due to a local deity. IUCN (1986) emphasised the role of TEK in providing knowledge about biological resources, their management through sustainability, and use in education and environmental assessment.

Realising the importance of TEK, a Traditional Knowledge Digital Library (TKDL), a collaborative project by organisations such as the National Institute of Science Communication and Information Resources (NISCAIR), the Council of Scientific and Industrial Research, the Ministry of Science & Technology and the Department of AYUSH, the Ministry of Health and Family Welfare, was implemented at NISCAIR. Experts, patent examiners, IT experts, scientists and technical officers are also working on the development of creating a TKDL for Indian Systems of Medicine that includes traditional medicine systems such as Ayurveda, Unani, Siddha and Yoga. The project involves documentation of the traditional knowledge available in the public domain.

12.3 SUMMARY

- Biodiversity is important for the sustenance of life and needs to be conserved. Biodiversity needs to be conserved at the genetic, species and ecosystem levels. Some areas that possess a huge number of rare fauna and flora have been designated as protected areas.
- Approaches for the biodiversity conservation range from protection of a single species to restoration of habitat and ecosystem. Ecosystem-based approaches prove useful because flagship species can be conserved along with other species. Endangered species need to be protected on a priority basis. The integrated landscape approach proves useful for long-term conservation.
- *In-situ* and *ex-situ* conservation techniques are followed to achieve protection of species. In the *in situ* conservation process, species are conserved in their native habitat, while in the e*x situ* conservation strategy, species are removed from habitat and maintained in captivity. National parks, wildlife sanctuaries, bird sanctuaries, wetlands, and biosphere reserves are zones of *in-situ* conservation.
- Protection of endangered species is done mainly in *ex-situ* conditions. Plant species are maintained in botanical gardens while animals are kept in zoological gardens. Breeding of animals under laboratory conditions is done, followed by their reintroduction in their natural habitat. The germplasm in plant species can be conserved in seed banks.
- TEK is important for biodiversity conservation. Information covers various aspects such as ecosystem management, medicine, agroecosystems, and wildlife. There is an immediate requirement for conservation of TEK.

12.4 TERMINAL QUESTIONS

1. Describe protected areas and mention their importance.

2. List the merits and demerits of habitat-based biodiversity protection.
3. Define flagship species. Discuss in brief their role in conservation.
4. Differentiate between *in situ* and *ex situ* conservation.
5. List the two problems associated with captive breeding programmes. Describe the methods to curtail them.
6. Tissue culture technique is useful. Justify the statement, citing examples.
7. Conservation of plant germplasm is carried out by NBPGR. Justify the statement, giving a suitable explanation.

12.5 ANSWERS

Self-Assessment Questions

1. a) i) False; ii) True; iii) True; iv) False; v) True

   b) i) National Board for Wildlife
      ii) International Union for Conservation of Nature
      iii) Commission on National Parks and Protected Areas
      iv) Sustainable Development Goal

2. a) i) Flagship species
      ii) Habitat based
      iii) Umbrella
      iv) Recalcitrant
      v) Corridors
      vi) Arboreta

   b) i) ecotones
      ii) buffer zone
      iii) Sacred groves
      iv) wetland
      v) mangroves
      vi) mangroves

   c) i) False; ii) True; iii) True; iv) False;
      v) True; iv) False.

Terminal Questions

1. Refer to Section 12.2.
2. Refer to Section 12.2.

3. Refer to Section 12.2.
4. Refer to Subsections 12.2.1 and 12.2.2.
5. Refer to Subsection 12.2.2.
6. Refer to Subsection 12.2.2.
7. Refer to Subsection 12.2.2.

Acknowledgement for Figures

Elephant, Chimpanzee and Rhino pictures are provided by WWF-Canon Michel GUNTHER.

Fig. 12.1 : https://www.insightsonindia.com/2024/03/29/eturnagaram-amrabad-wildlife-sanctuaries/

Fig. 12.2 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig. 12.3 : http://enviscpreec.blogspot.com/2014/06/sacred-groves-of-meghalaya.html

Fig. 12.4 : https://www.tnpscthervupettagam.com/currentaffairs-detail/judgement-on-eco-sensitive-zones

Fig.12.5 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.6 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.7 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.8 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.9 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.12 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.13 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.14 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.15 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.16 : https://egyankosh.ac.in/bitstream/123456789/12945/1/Unit-10.pdf

Fig.12.10 : https://whc.unesco.org/en/statesparties/in

Fig.12.11 : https://en.wikipedia.org/wiki/Keoladeo_National_Park#/media/File:Family_Breakfast.jpg

Suggested Readings

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UNIT 13

MOLECULAR ECOLOGY AND ITS APPLICATIONS

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THE PEOPLE'S
UNIVERSITY

Structure

13.1 Introduction
    Objectives
13.2 Sustainable Development
13.3 Natural Resource in Changing Environment
13.4 Molecular Ecology
13.5 Genetic Analysis of Single Populations
    Hardy-Weinberg Equilibrium
    Population Bottlenecks
    Founder Effect
13.6 Genetics Analysis of Multiple Populations: Natural Selection
    Reproduction
    Inbreeding
13.7 Quantifying Population Subdivision
    Direct Methods
    Indirect Methods
    Gene Flow Discrepancies
    Dispersal Ability
13.8 Molecular Markers and Phylogeography
13.9 Molecular Approaches to Behavioral Ecology
    Mating Systems
    Monogamy, Polygamy and Promiscuity
    Mate Choice
13.10 Conservation Genetics
13.11 Terminal Questions
13.12 Answers

13.1 INTRODUCTION

Over the past 20 years, molecular biology has transformed ecological research. Scientists can now easily study the genetics of individuals, populations, and species, providing new insights into how plants, animals, fungi, algae, and bacteria evolve and interact. Molecular markers help researchers measure genetic diversity, track animal movements, identify species, detect inbreeding, and even retrace how species have spread over time. These tools are not just useful for academic research—they also help answer real-world questions, like which endangered species are at the highest risk due to inbreeding or how much crossbreeding has occurred between genetically modified crops and wild plants.

Advancements in technology have made genetic analysis more affordable and accessible. Now, scientists can use small DNA samples, like hair or scat, to study elusive animals like jaguars and bears. They can even determine where invasive species came from with just a few samples. This chapter will explore how molecular markers provide such valuable information. In simple terms, they analyse DNA, which is an incredibly diverse molecule found in most of the living organisms. By studying DNA, scientists uncover vast amounts of genetic information. But before diving into modern methods, we'll first look at how studying proteins in fruit flies changed our understanding of ecology and evolution forever.

Ecology is the study of how living things interact with each other and their environment. In the past, scientists mainly used field observations and experiments to understand these interactions. They relied on physical traits like body shape, behaviour, or physiology to gather data. These traditional methods greatly expanded our knowledge of ecosystems and species, but they had limitations.

For example, if a butterfly population is declining, scientists might suspect low genetic diversity is making them more vulnerable to diseases. Without genetic data, they would have to guess by looking at wing patterns, assuming that populations with more varied patterns also have more genetic diversity. However, this approach has a flaw: an organism's appearance (phenotype) doesn't always directly reflect its genetic makeup (genotype) because environmental factors can influence physical traits. A good example of this is the African butterfly *Bicyclus*, whose wing patterns change based on how much rain falls while it is developing. The same genetic makeup can produce different appearances depending on the season. This ability, called *phenotypic plasticity*, means that physical traits alone can sometimes mislead scientists. Another striking example is the oak caterpillar *Nemoria arizonaria* in the southwestern U.S. If it eats oak catkins (flower clusters), it develops into a catkin lookalike. If it eats leaves, it turns into a twig mimic. This change is triggered by diet alone, and for years, scientists thought these were two different species (Table 13.1).

Table 13.1: Some examples of how environmental factors can influence phenotypic traits, leading to phenotypic plasticity.

Characteristic	Environmental Influence	Example
Gender	Temperature during embryonic development	Eggs of the American snapping turtle (*Chelydra serpentina*) develop primarily into females at cool temperatures, primarily into males at moderate temperatures, and exclusively into males at warm temperatures.

Growth patterns in plants	Soil nutrients and water availability	Southern coastal violet (*Viola septemloba*) allocated a greater proportion of biomass to roots than to shoots in poor-quality environments.
Leaf size	Light intensity	Dandelions (*Taraxacum officinale*) produce larger leaves under conditions of relatively strong light intensity.
Migration between host plants	Age and nutritional benefit of host plants	Diamondback moths (*Plutella xylostella*) are most likely to migrate as the juvenile stage fed on mature plants.
Feeding-related morphology	Food availability	Sea urchin larvae (*Strongylocentrotus purpuratus* and *S. franciscanus*) produce larger food-gathering arms and smaller stomachs when food is scarce.
Plumage colouration	Carotenoids in diet	The plumage of male house finches (*Carpodacus mexicanus*) shows varying degrees of red, orange, and yellow depending on the carotenoids in each bird's diet.

As physical traits can be influenced by the environment, scientists needed a more reliable way to study genetic diversity. This led to the development of molecular ecology. About 40 years ago, researchers found a way to measure genetic differences by studying proteins. This breakthrough allowed scientists to directly analyse genetic variation and track how genes (and individuals) move between populations. Many consider this discovery the starting point of molecular ecology.

Objectives

After studying this unit, you should be able to:

- ❖ understand the basis of Molecular clock and phenotypic plasticity;
- ❖ describe the Hardy Weinberg Equilibrium and its assumptions; and
- ❖ explain the different type of Mating system and Mate Choice.

13.2 SUSTAINABLE DEVELOPMENT

The idea of sustainable development has become well-known in recent years as more people at local, national, and global levels have started understanding how important the environment is. This includes not only individuals and communities but also governments. One of the key global goals, the 7th Millennium Development Goal, focuses on protecting the environment by promoting sustainable development and making sure natural ecosystems remain healthy for future generations.

Before the 1980s, many countries did not consider environmental issues as part of their development plans. As a result, the environment suffered. Rapid economic growth over the past 150 years led to serious problems such as damage to the ozone layer, air and water pollution, loss of forests and biodiversity, and extinction of plants and animals. By the 1980s, people started to realise that environmental problems were affecting human life and health. This led to greater attention to ecology and the need to protect nature. The fast use of resources, along with growing industrial and agricultural activity, placed huge pressure on the Earth's natural resources.

Often, development projects focus on using natural resources for profit. This has changed the way people think about who has the right to use those resources. As a result, poor communities have been left with fewer natural resources for their basic needs. Either these resources are taken away, or the environment is damaged so much that these resources can no longer renew themselves. To be truly sustainable, development must consider social, cultural, environmental, and economic factors and think about both short-term and long-term impacts.

The Brundtland Commission defined sustainable development as:
"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
This definition includes two key ideas:

1. The needs of the world's poor should be a top priority.
2. There are limits to what the environment can provide, especially because of current technology and how society is organised.

So, both rich and poor countries, no matter their economic system, must aim for sustainability. Their approach might differ, but they should agree on the basic idea and work together to reach it.

Development means improving the economy and society over time. But for development to truly last, it must also be physically sustainable, and this means protecting the environment. And that can't happen unless policies also address fair access to resources and a fair distribution of the costs and benefits of development.

13.3 NATURAL RESOURCE IN CHANGING ENVIRONMENT

There is an urgent need to think seriously about how we are destroying natural resources. With the fast-growing human population and advanced technology, we are using these resources more than ever before. To avoid running out, we must use them wisely. This means learning how to manage and conserve natural resources properly. Management and conservation involve using resources carefully and scientifically so that they last longer and maintain good quality. For example, India produces only half of the petroleum it needs and imports the rest. Among petroleum products, natural gas is widely used, and its use has increased ten times over the last 20 years. To save fossil fuels from running out, we need to switch to alternative energy sources like solar energy, wind energy, and biomass. Biogas is one such renewable energy source. It is made from animal waste, water plants, and other organic materials. India is a leader in using and developing biogas. It is cheap, clean, and saves time and labour. Biogas can be used for cooking, lighting, and even in vehicles.

The World Conservation Strategy says that natural resource management means using land, water, and living things in a way that gives the most benefit to people today without harming the ability of future generations to meet their needs. But today, rapid development, population growth, and migration are making it harder for people to meet their basic needs. High demand for firewood, forest products, and pollution from industries, along with the illegal trade of rare animals and medicinal plants, are damaging biodiversity, which is the variety of life on Earth. Also, expanding modern agriculture by growing improved plant varieties over large areas is harming biodiversity even more. This loss of biodiversity is a big problem because it threatens the balance of nature and long-term human development.

The main reasons why natural resources are being used up so quickly are population growth, economic growth, and the way development is happening. This includes the type of technology we use, how our economies are structured, and our habits of producing and consuming goods. In the next 50 years, the global population is expected to grow by 50%, which will put huge pressure on the environment. If people in developing countries reach the same level of wealth and comfort as people in developed countries today, the expected use of natural resources could double or even increase five times.

Unless we make big improvements in technology or change the way we consume resources, this rising demand, especially from developing countries, could cause more environmental damage than any efficiency improvements made in rich countries. Our wealth and comfort depend on using natural resources like energy, land, and raw materials but if we keep increasing our use of these resources, it could lead to serious environmental problems, such as ecosystem collapse and even threats to human security. Due to these reasons, the sustainable use and careful management of natural resources have become very important. This has been a major global concern since the 1992 Earth Summit in Rio de Janeiro.

In the past 50 years, humans have changed natural ecosystems faster and more widely than ever before, mostly to meet the rising demand for food, fresh water, wood, fuel, and other resources. While this has improved living standards and supported economic growth, it has also damaged many ecosystems, as highlighted in the Millennium Ecosystem Assessment (2005).

13.4 MOLECULAR ECOLOGY

In the last 25 years, molecular biology has completely changed the way we study ecology. Scientists can now easily study the genes of individual organisms, whole populations, and even entire species. These genetic tools have given us a lot of new information and exciting discoveries about how plants, animals, fungi, algae, and bacteria live and evolve.

Molecular markers are the special tools that help study DNA. This technique can help scientists to:

- measure genetic diversity (how different genes are within a population).
- track the movement of animals or people,

- detect inbreeding (when close relatives breed),
- identify remains of dead individuals,
- discover new species, and
- study how species have moved or spread over time.

Newer and more advanced genomic technologies help us understand how genes work and how species adapt to changes in the environment. This has led to the creation of a new field called ecogenomics, which combines ecology with molecular biology to understand how an organism's genes interact with its environment. These tools are not only interesting for scientists, but they are also helpful in solving real-world ecological problems like figuring out which endangered animals are at risk from inbreeding or how much mixing has happened between genetically modified crops and their wild relatives. Today, it's easier and cheaper than ever to get genetic information. This means scientists can now find out where invasive species came from using just a few samples or track rare animals like jaguars or bears using just their hair or droppings.

13.5 GENETIC ANALYSIS OF SINGLE POPULATIONS

A population is a group of individuals from the same species that live in the same area and can potentially reproduce amongst themselves. While this definition seems simple, in reality, populations don't always have clear boundaries.

For example, many bird species migrate, meaning a single wintering group may include birds from different breeding populations. The situation is even more complicated in the common green darner dragonfly (*Anax junius*). Some of its larvae take three months to develop into adults, while others take eleven months. Since they mature at different times, they can't always reproduce with each other. However, because their offspring may still interbreed in later generations, they are considered part of the same population.

Another challenge in defining populations is delayed development (diapause). Some plants and animals have seeds or eggs that stay dormant for years before growing. For instance, the desert plant *Linanthus parryae* can keep seeds in the soil for up to six years, waiting for the right conditions to sprout. Similarly, freshwater zooplankton can remain in sediments for decades before hatching. This example makes it easy to underestimate the true size of a population.

Population boundaries can also change based on interactions with other species. For example, the range of a flowering plant population depends on the movement of its pollinators, which can vary yearly. The fungus *Daldinia loculata*, which grows on burnt trees, spreads when insects carry its reproductive cells between trees. This means its population isn't limited to a single tree but instead depends on insect movement.

As wild populations are often unpredictable, scientists usually define populations at the beginning of their research as a way to organise their studies. However, these boundaries can change as new ecological or genetic data become available. Since molecular ecology focuses on understanding wild populations, scientists use genetic tools to study how populations change and interact over time.

13.5.1 Hardy-Weinberg Equilibrium

Population genetics explores the genetic composition of populations and how it changes over time. It combines principles of genetics and evolutionary biology to explain genetic variation, adaptation, and speciation. This field of study provides an insights into the evolutionary forces that drive biodiversity by examining the factors like mutation, natural selection, genetic drift, and gene flow shape genetic diversity.

A central concept in population genetics is the gene pool—the total genetic material within a breeding population. Genetic diversity within this pool is essential for species survival and adaptability. The field investigates how genetic variations arise, persist, and influence traits, ultimately affecting an organism’s fitness—its ability to survive and reproduce in its environment.

Population genetics is based on several key principles, which are briefly described below:

Hardy-Weinberg Equilibrium: This principle acts as a baseline, predicting that a population’s genetic structure will remain stable over generations if no evolutionary forces are at play. In the absence of mutation, selection, migration, genetic drift, or non-random mating, allele and genotype frequencies remain unchanged. Any deviation from this equilibrium signals evolutionary changes.

Genetic Drift: Random fluctuations in allele frequencies occur due to chance events, particularly in small populations. This process can reduce genetic diversity, leading to the fixation (100% frequency) or loss of certain alleles over time.

Gene Flow: The transfer of alleles between populations through migration and interbreeding introduces new genetic material. Gene flow helps maintain genetic diversity and can prevent populations from becoming too genetically distinct.

Natural Selection: A key driver of evolutionary change, natural selection favours alleles that enhance survival and reproduction. Over time, beneficial alleles become more common, shaping the genetic makeup of populations.

Mutation: As the primary source of genetic variation, mutations introduce new alleles by altering DNA sequences. While most mutations are neutral or harmful, some provide adaptive advantages under specific environmental conditions.

The interaction of evolutionary forces shapes genetic diversity within populations, influencing processes such as adaptation to new environments and speciation. For example, in small, isolated populations, genetic drift can rapidly fix certain alleles, a phenomenon known as the founder effect. Likewise, strong selective pressures in changing environments can drive the rapid spread of beneficial alleles, leading to local adaptations.

Genetic diversity is shaped by multiple factors and varies significantly among populations. Key determinants include genetic drift, population bottlenecks, natural selection, and reproductive strategies. However, these processes do not act in isolation. For instance, a population's recovery from a bottleneck depends partly on its reproductive ecology. Moreover, predicting the exact impact of any single factor is challenging, as no two populations respond identically. Nevertheless, certain factors universally influence genetic diversity, and these will be explored in the following sections.

Genetic drift is a random process that alters allele frequencies between generations due to chance. Since reproductive success varies among individuals, some alleles are passed on more frequently than others, leading to fluctuations in allele frequencies over time. Unlike natural selection, genetic drift causes non-adaptive evolutionary change.

The effects of genetic drift are strongest in small populations, where it can rapidly drive alleles to fixation or extinction, ultimately reducing genetic diversity. While drift also affects large populations, its impact takes longer to become significant.

Genetic drift plays a crucial role in population genetics and is central to the concept of **effective population size (Ne)**—a key measure of a population's genetic structure. Since **Ne** and genetic drift are closely linked, the next section will examine how **Ne** differs from census population size (**Nc**), how it influences genetic drift, and its broader implications for genetic diversity.

13.5.2 Population Bottlenecks

As previously noted, a population bottleneck reduces effective population size (Ne) and, consequently, overall genetic diversity. Given their significant impact, bottlenecks warrant a more detailed discussion. Methods for quantifying their effects on Ne often rely on long-term demographic data, which are rarely available. Instead, biologists frequently infer past bottlenecks by analysing populations with unusually low genetic diversity, attempting to determine whether a historical bottleneck could explain the current genetic depletion.

Detecting past reductions in population size is challenging. The severity of a bottleneck depends on both the extent of population decline and the speed of recovery. Generally, the initial loss of alleles is proportional to the reduction in population size. However, genetic drift continues to erode diversity while the population remains small. Consequently, populations that recover slowly tend to lose more genetic variation than those that rebound quickly.

Identifying bottlenecks is further complicated by the fact that different measures of genetic diversity do not decline uniformly. Allelic diversity typically decreases because rare alleles are lost, often leading to a drop in expected heterozygosity (He) under Hardy-Weinberg equilibrium (HWE). However, observed heterozygosity (Ho) may not decline immediately and can sometimes temporarily exceed expectations under HWE. This heterozygosity excess can serve as an indicator of past bottlenecks, though it requires data from many polymorphic loci and is only effective at detecting relatively recent events.

If genetic samples are available from multiple generations, past bottlenecks can sometimes be inferred by analysing changes in allele frequencies over time. Since a bottleneck reduces **effective population size (Ne),** it also increases the rate of genetic drift, leading to greater fluctuations in allele frequencies between generations. This inflated variance can serve as evidence of a bottleneck occurring between two sampling periods.

Simulations suggest that the temporal variance method has an 85% probability of detecting a bottleneck after a single generation if data are available from at least five highly variable loci and thirty individuals per sampling period. However, this method becomes less effective for populations that have experienced prolonged bottlenecks (>3–5 generations) because ongoing allele loss prevents further variance. Once an allele is lost, its frequency remains at zero, leading to an overestimation of Ne.

A study on western mosquitofish tested different methods for detecting past bottlenecks. Experimental populations, founded by 2–16 individuals, were monitored for two to three generations, and their genetic diversity was assessed. The most effective indicator was the temporal variance in allele frequencies, which was inversely proportional to the size of the founding population. Other useful measures included allelic diversity and expected heterozygosity (He), while observed heterozygosity (Ho) and the proportion of polymorphic loci did not show a clear relationship with bottleneck severity.

Results from experimental studies may not always apply to natural populations. The ability to detect bottlenecks depends on several factors, including:

- **Marker variability**: Some genetic markers are more informative than others.
- **Bottleneck severity and duration**: More severe and prolonged bottlenecks lead to greater allele loss.
- **Sampling strategy**: Using too few loci can lead to misleading conclusions.

For instance, a study on eastern mosquitofish using allozyme data found that **allelic diversity** was a more reliable indicator of bottlenecks than temporal variance in allele frequencies. This highlights the importance of using multiple genetic measures when assessing past bottlenecks.

Conflicting results can arise when comparing nuclear and organelle markers. Because organelle genomes (e.g., mitochondrial DNA) have smaller population sizes, they are more sensitive to bottlenecks and may exaggerate genetic diversity loss. This pattern was observed in Scandinavian brown bears, which underwent a severe bottleneck between the mid-1800s and 1930, dropping from ~5000 to ~130 individuals across four subpopulations. Today, the population has rebounded to ~1000 bears, yet genetic diversity concerns remain.

- Mitochondrial DNA (mtDNA) analysis of 380 bears revealed only two haplotypes, indicating that most mtDNA variation was lost during the bottleneck.

- Microsatellite DNA (nuclear markers), however, showed He values comparable to North American brown bear populations, suggesting that many nuclear alleles persisted within subpopulations.

This case illustrates how different genetic markers can provide contrasting perspectives on the long-term effects of bottlenecks. Whereas mitochondrial data suggest a lasting impact on genetic diversity, nuclear markers indicate that highly polymorphic loci have been largely preserved.

13.5.3 Founder Effect

Studies on human-introduced species provide valuable insights into how bottleneck size and recovery speed affect long-term genetic diversity. These introductions often involve a founder effect, where the initial population carries only a subset of the genetic variation present in the source population. Unlike natural bottlenecks, human-mediated introductions are advantageous for study because the timing and size of the founding population are often well-documented.

One notable example is the Mauna Kea silversword (*Argyroxiphium sandwicense* ssp. *sandwicense*) in Hawaii, which has experienced at least two documented bottlenecks in recent history:

1. First Bottleneck (~100–150 years ago):
    - The spread of introduced ungulates reduced the population to fewer than 50 plants.
    - Despite this decline, microsatellite data showed no significant loss of genetic diversity in terms of allelic diversity (A) or heterozygosity (He) (Friar et al., 2002).
    - The species' long lifespan (30–50 years before flowering) likely contributed to its rapid recovery, as the bottleneck lasted only one or two generations.
2. Second Bottleneck (1973):
    - A reintroduced population was founded by just two or three transplanted individuals.
    - Despite expanding to over 1500 individuals, genetic diversity remains extremely low due to the severity of the initial bottleneck (Friar et al., 2002).
    - This case demonstrates that while a moderate bottleneck can be mitigated by rapid recovery, an extremely severe bottleneck can cause lasting genetic depletion.

Avian Introductions and Bottleneck Effects

A broader review of avian introductions to islands also investigated how founding population size and post-bottleneck growth rates influence genetic diversity. Using allozyme data, the study compared the genetic variation of island populations to their mainland source populations. Surprisingly, island populations did not always exhibit lower genetic diversity. Instead, genetic variation was correlated with:

- Initial population size – Larger founding groups retained more genetic diversity.
- Population growth rate – Rapid expansion helped maintain genetic variation.

These findings support the idea that bottlenecks only significantly reduce genetic diversity when they are both severe and prolonged (Fig. 13.1). Allozyme data from species like starlings, greenfinches, chaffinches, common mynas, and house sparrows showed that: Larger founding populations retained higher He. Faster population growth helped maintain genetic diversity. He was generally lower in introduced populations than in their source populations, but some cases showed higher He, likely due to rapid expansion. These findings suggest a positive correlation between genetic diversity, initial population size, and growth rate (Fig. 13.1).

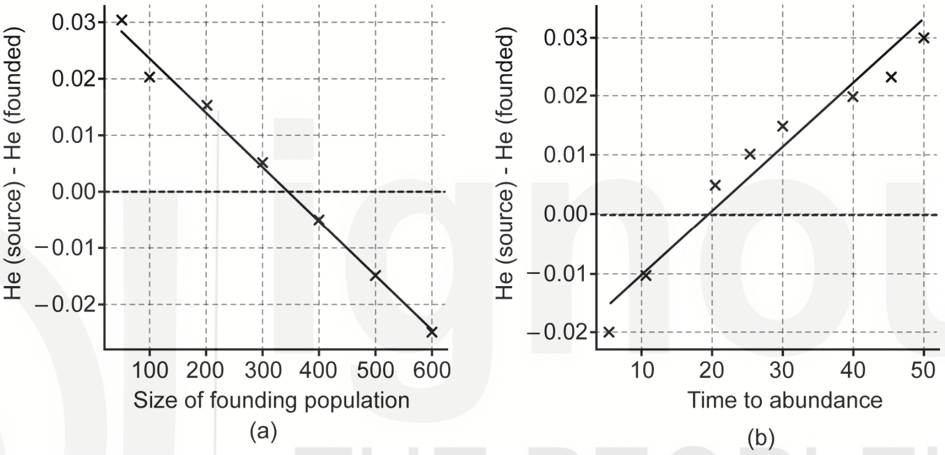

Fig. 13.1: The heterozygosity (He) of introduced bird populations in New Zealand and Australia was influenced by both a) founding population size; and b) time to abundance.

SAQ 1

a) How does migration affect population boundaries?

b) How does delayed development affect population estimates?

c) What is the gene pool?

d) What is Hardy-Weinberg equilibrium?

e) What factors can disrupt Hardy-Weinberg equilibrium?

f) What is a population bottleneck?

g) What is the temporal variance method?

13.6 GENETICS ANALYSIS OF MULTIPLE POPULATIONS: NATURAL SELECTION

In addition to non-adaptive processes, natural selection shapes genetic variation by influencing the reproductive success of different genotypes.

Depending on the type of selection, allele frequencies may increase or decrease genetic diversity:

- Stabilising selection reduces variation by favouring the average phenotype, eliminating extremes.
- Directional selection typically decreases diversity through:
  - i) Negative (purifying) selection, which removes harmful mutations.
  - ii) Positive selection, which favours beneficial mutations. During this process, transient polymorphism occurs, temporarily increasing diversity before the allele reaches fixation, making the locus monomorphic.

Disruptive (diversifying) selection increases genetic variation by favouring extreme phenotypes over intermediates.

Figure 13.2 shows the three common selection modes influence phenotypic and genetic variability within a population. In Figure 13.2, each diagram shows phenotype frequency by the distribution curve, the dashed line represents the mean phenotype in the parental generation, and the cross marks individuals with lower fitness. Directional selection favours one extreme phenotype, shifting the distribution. Stabilising selection favours the intermediate phenotype, reducing variation. Disruptive selection favours multiple extreme phenotypes, eliminating intermediates.

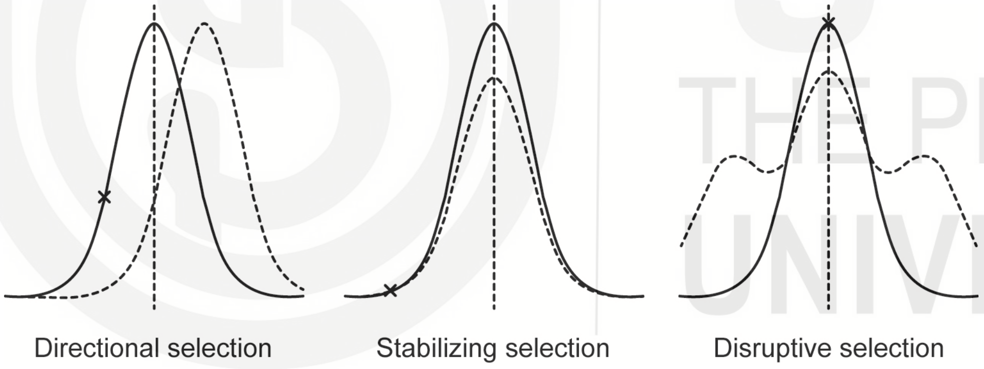

Fig. 13.2: Modes of Selection and Their Impact on Variation.

Balancing selection refers to evolutionary processes that maintain genetic diversity by favouring certain alleles in some conditions while selecting against them in others. In large populations, where genetic drift has minimal influence, balancing selection can shape the genetic diversity of non-neutral loci.

One common form is heterozygote advantage (overdominance), where heterozygotes have higher fitness than homozygotes. A well-known example is the sickle-cell haemoglobin allele (S) in African and Mediterranean populations. While SS individuals suffer from sickle-cell anaemia and AA individuals lack malaria resistance, SA individuals have mild anaemia but greater resistance to *Plasmodium falciparum* malaria, maintaining both alleles in malaria-prone regions.

Another form is frequency-dependent selection, where a genotype's fitness depends on its frequency in a population. Positive frequency-dependent selection favours common traits, as seen in *Heliconius erato* butterflies, where the dominant local colour pattern deters bird predation. Negative frequency-dependent selection favours rare traits, such as in elder-flower orchids. Pollinators, expecting a nectar reward, shift to less common flower colours after an unrewarded visit, leading to a dynamic balance between yellow and purple flowers over time.

13.6.1 REPRODUCTION

Reproductive mode plays a crucial role in shaping genetic diversity. Sexual reproduction, despite its twofold cost where females produce both males and females, effectively halving reproductive output compared to asexual reproduction, remains dominant in multicellular eukaryotes. The primary advantage of sex is recombination, which generates novel genotypes that enhance adaptability to changing environments, leading to higher genetic diversity in sexual populations.

Comparisons within a single species offer the best insights into the effects of reproduction on genetic variation. For example, in the aphid *Sitobion avenae*, sexual reproduction is common in colder European regions where overwintering eggs are necessary, while asexual reproduction dominates in milder climates. A study using microsatellites found that sexually reproducing Romanian aphids had significantly higher genetic diversity than largely asexual French populations, where 94% of Romanian aphids had unique genotypes compared to just 28% in France. Similarly, in *Rhopalosiphum padi* aphids, asexual populations had lower genetic diversity (He = 0.60, 6.6 alleles per locus) than sexual ones (He = 0.642, 11.3 alleles per locus).

In flowering plants, an analysis of 653 allozyme studies found no significant difference in genetic diversity between sexual and mixed reproductive populations. However, later research using RAPD and microsatellite markers indicated that outcrossing species generally exhibit higher genetic diversity. These findings highlight that while asexual reproduction can sustain genetic diversity, sexual reproduction often leads to greater genetic variation, enhancing evolutionary potential.

Table 13.2 compares genetic diversity (*He*) across three modes of reproduction using RAPD and microsatellite data. The lowest genetic diversity is observed in the selfing mode of reproduction, while the mixed mode (a combination of selfing and outcrossing) exhibits higher genetic diversity than selfing. The highest genetic diversity is seen in the outcrossing mode of reproduction. Microsatellite markers provide more sensitive and detailed genetic information compared to RAPD markers. Observed heterozygosity (*Ho*) is strongly influenced by the mode of reproduction: selfing leads to low *Ho*, whereas outcrossing maintains high *Ho*.

Table 13.2: Mode of reproduction based on RAPD and microsatellite data.

Mode of Reproduction	**RAPD Data**		**Microsatellite Data**		
	n	**He**	**n**	**He**	**Ho**
Selfing[1]	10	0.12^{b}	15	0.41^{b}	4
Mixed (selfing and outcrossing)	8	0.18^{b}	15	0.60^{c}	13
Outcrossing	38	0.27^{c}	71	0.65^{c}	60

13.6.2 INBREEDING

Inbreeding occurs when individuals mate with relatives. While it does not change allele frequencies, it increases homozygosity across all loci, reducing individual genetic diversity. This leads to lower observed heterozygosity (Ho) but does not immediately affect expected heterozygosity (He). Over time, inbreeding can reduce fitness levels, potentially depleting genetic diversity through increased mortality.

Traditionally, inbreeding was estimated using pedigree records, which are impractical for most wild populations. Molecular markers now provide a better alternative by identifying alleles identical by descent (IBD)—alleles inherited from a common ancestor. Individuals with two IBD alleles are autozygous and always homozygous at that locus, while allozygous individuals have alleles that are not IBD and can be either homozygous or heterozygous.

A key indicator of inbreeding is a heterozygote deficiency, leading to deviations from Hardy-Weinberg equilibrium (HWE). The inbreeding coefficient (F) quantifies this effect:

$$F = \frac{Hs - Hi}{Hs}$$

where Hi is the observed heterozygosity and Hs is the expected heterozygosity under HWE. F = 0 indicates no inbreeding, while F = 1 means complete homozygosity. However, heterozygote deficits can also result from factors like population substructure, null alleles, or natural selection rather than inbreeding alone. Table 13.3 provides estimates of F in wild populations.

Table 13.3: Inbreeding Coefficients (F) Across Different Species and Reproductive Strategies.

Species	Marker	Inbreeding Coefficient (F) within Populations	Reference
Aphids (*Rhopalosiphum padi*)	Allozymes	Asexual: 0.339 Sexual: 0.020	Delmotte *et al.* (2002)
	Microsatellites	Asexual: -0.499 Sexual: 0.182	
Aphids (*Sitobion avenae*)	Microsatellites	Asexual: 0.033 Sexual: 0.244	Simon *et al.* (1999)
Lemurs (*Propithecus verreauxi*)	Microsatellites	Offspring: -0.068 Adults: 0.003	Lawler, Richard, and Riley (2003)
Greenfinch (*Carduelis chloris*)	Allozymes	Native (continental): 0.133 Introduced (island): 0.124	Merilä, Björklund, and Baker (1996)
Alpine pennycress (*Thlaspi caerulescens*)	Allozymes	Metal-tolerant: 0.217 and 0.501 Metal-intolerant: 0.578 and 0.704	Dubois *et al.* (2003)
Common ash (*Fraxinus excelsior*)	Microsatellites	Seeds: 0.163 Adult trees: 0.292	Morand-Prieur *et al.* (2002)

Genetic diversity is a key focus in the analysis of single populations. The present Unit explored methods for measuring genetic diversity and the factors that influence it. Figure 13.3 shows a few main factors that influence levels of genetic diversity within populations. The figure highlights that while a greater number of processes reduce genetic diversity than increase it, still most of the populations maintain high diversity. One major factor that enhances genetic diversity is the gene flow that plays a crucial role in population genetics, will be discussed in the next sections of the Unit, as it involves interactions between multiple populations.

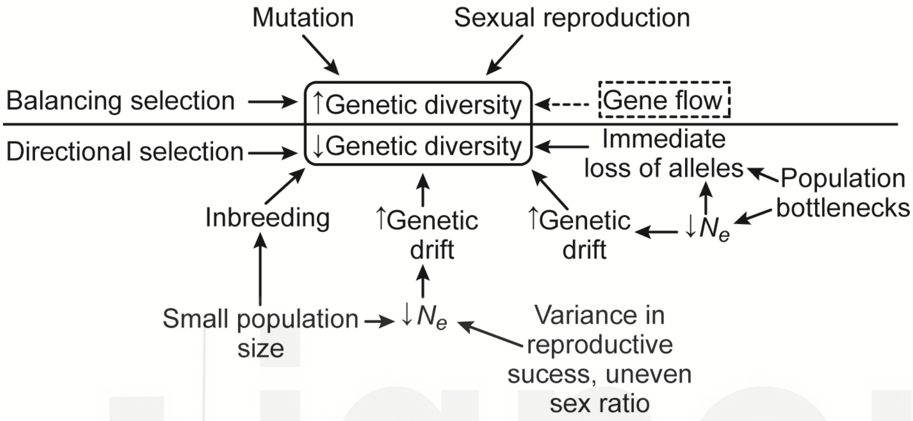
Mutation
Sexual reproduction
Balancing selection
↑Genetic diversity
Gene flow
Directional selection
↓Genetic diversity
Immediate loss of alleles
Population bottlenecks
Inbreeding
↑Genetic drift
↑Genetic drift
↓N_e
Small population size
↓N_e
Variance in reproductive sucess, uneven sex ratio

Fig. 13.3: An overview of some of the main factors that influence levels of genetic diversity within populations.

13.7 QUANTIFYING POPULATION SUBDIVISION

With the exception of rare or endangered species with limited distributions, nearly all species show some level of genetic differentiation between populations. If populations had identical allele frequencies, it would imply random mating across the entire species, showing a scenario unlikely for species with multiple populations.

For years, European eels (*Anguilla anguilla*) were considered an exception. Despite overwintering in separate locations across Europe, all individuals migrate to the Sargasso Sea to reproduce, supporting the idea of species-wide panmixia. Early studies using allozymes and mitochondrial DNA found no genetic structure. However, later research using microsatellite markers detected weak but significant genetic differences among eels from different overwintering sites, suggesting that reproduction may occur more frequently between individuals from similar latitudes. Such subtle population divisions can be difficult to detect without molecular markers. The following section will explore methods for analysing genetic data to determine whether populations are genetically distinct.

Before quantifying gene flow, it is important to distinguish it from dispersal and migration. Dispersal refers to the movement of individuals or propagules between locations or populations, while migration involves periodic, often seasonal, movement along a specific route. However, gene flow only occurs if individuals successfully reproduce in their new location.

Although dispersal is sometimes used as a proxy for gene flow, which can be misleading. Understanding the movement of individuals, gametes (e.g., pollen), and genes between populations is crucial in ecology and population genetics, as gene flow influences population size, genetic diversity, local adaptation, and even speciation. However, measuring these movements is complex.

The subsequent subsections will explore three main approaches to estimating dispersal and gene flow: direct methods, indirect methods, and assignment tests.

13.7.1 Direct Methods

The colonisation of new habitats, such as freshwater zooplankton invading new ponds (Jenkins, 1995), provides clear evidence of dispersal. However, such observations reveal little about the frequency or extent of movement between established populations. A more detailed direct method is mark-recapture, where individuals are tagged using rings, paint, or other markers. Dispersal is confirmed when marked individuals are later recaptured at a different location. However, this method is time-consuming and has low success rates, as many individuals are never recaptured.

A more advanced tracking method involves radio or radar tracking, which has been used to monitor migration in birds and butterflies. While expensive and labour-intensive, it provides data on all movements, not just recapture locations, making it useful for studying foraging behaviour and migration routes. Another technique uses stable isotopes as markers, such as the introduction of ^{15}N into over 1.5 million aquatic stonefly larvae. Screening of adults in nearby streams detected only a few enriched individuals, suggesting low dispersal rates. Traditional mark-recapture methods, which would have targeted fewer individuals, might have missed this evidence entirely.

While these methods estimate dispersal, they do not confirm gene flow, as they do not determine whether immigrants successfully reproduce. Parentage analysis, commonly used in plants, provides more direct evidence of gene flow. In a Spanish population of the cherry tree *Prunus mahaleb*, researchers compared the genotypes of 180 adult trees with those of 95 naturally dispersed seeds. Of these, 78 matched local maternal trees, while 17 came from outside the population, indicating long-distance seed dispersal by frugivores. A similar approach has been used to study pollen-mediated gene flow by comparing seedling genotypes with potential pollen donors.

Although parentage analysis offers a comprehensive view of gene flow, it is impractical for large populations or species with extensive dispersal. A common challenge across all direct dispersal studies is that they are expensive, time-consuming, and limited to small sample sizes. Furthermore, except for parentage analysis, dispersal does not necessarily equate to gene flow. Due to these limitations, researchers increasingly rely on indirect estimates of gene flow, which analyse genetic differentiation among populations. This method will be discussed in the next subsection.

13.7.2 Indirect Methods

After Wright (1951) introduced F-statistics, he showed a simple way to estimate gene flow between two populations using **FST**, a measure of genetic difference. The relationship is:

$$FST = \frac{1}{4Nem + 1}$$

where **Ne** is the effective population size, **m** is the migration rate, and **Nem** represents the number of breeding adults migrating between populations. Rearranging this formula gives:

$$Nem = \frac{1}{FST} - 1 \div 4$$

For example, in a study on scarlet tiger moths, **FST** was **0.009**, leading to an estimate of **27.5 individuals** migrating between the two populations each generation. This makes **Nem** a popular method for estimating gene flow from genetic data because it is easy to calculate.

Despite its usefulness, **Nem** has several limitations:

- It is based on the island model, which assumes an infinite number of populations of equal size, with no selection or mutation, and all populations exchanging migrants at the same rate.
- It assumes migration-drift equilibrium, meaning genetic differences caused by drift are balanced by gene flow. However, equilibrium is often disrupted by factors like habitat fragmentation, population bottlenecks, and recent range expansions.

A study on the whirligig beetle highlighted this issue. Genetic data suggested Nem = 2.12, but direct mark-recapture studies showed up to eight migrants arriving per season. Researchers found that frequent bottlenecks in the ponds sped up genetic drift, inflating FST and making Nem seem lower than actual dispersal rates.

Debates on Nem's Accuracy

Some studies find Nem matches real dispersal rates. A meta-analysis of 230 plant-feeding insect studies found that species with higher dispersal rates had higher Nem values. Another meta-analysis of 333 vertebrate and invertebrate species across different habitats found similar results. However, since FST is influenced by more than just gene flow and Nem relies on an oversimplified model, these estimates should be interpreted cautiously.

13.7.3 Gene Flow Discrepancies

No single method for calculating gene flow is completely reliable, so it's best to use multiple methods whenever possible. If different approaches give similar results, we can be fairly confident in our conclusions. However, discrepancies are common, and there are several reasons for this.

Indirect estimates, like Nem, may not accurately reflect gene flow because they rely on simplified models that do not always match real-world conditions. While assignment tests are a promising alternative, they still require thorough testing with different sample sizes, genetic markers, and population characteristics to ensure accuracy.

Direct methods also have limitations. Mark-recapture studies may underestimate dispersal if they are conducted at the wrong time or place. For example, a study on yellow-bellied marmots (Marmota flaviventris) found that radio tracking detected far more dispersal events (65% of males and 42% of females) than mark-recapture alone. Parentage studies can also be inconclusive if there are too many potential parents in a population.

Table 13.4 summarises the strengths and weaknesses of different methods for estimating dispersal and gene flow. It’s also important to note that even if dispersing individuals don’t reproduce, they can still impact ecosystems. For example, parasites and microbes can spread disease without needing to establish a breeding population. Hence, both dispersal and gene flow estimates are necessary for a complete understanding of population dynamics.

Table 13.4: Comparison of Methods for Estimating Dispersal and Gene Flow.

Category	Indirect (NemN_emNem)	Direct	Assignment tests
Assumptions	Population equilibrium, marker neutrality, island model	Capture–mark–recapture, radio tracking: negligible. Parentage: individual-specific genetic profiles	Linkage equilibrium, Hardy–Weinberg equilibrium
Number of populations feasibly studied	Many	Few	Many
Dispersal or gene flow	Gene flow	Mark–recapture, radio tracking = dispersal. Parentage = gene flow	Dispersal
Likelihood of detecting long-distance dispersal	Low if long-distance dispersal is rare	Radio tracking: high. Mark–recapture, parentage: low	Theoretically high, as long as migrants' source populations are genotyped
Dependence on sample size	Moderate	Radio tracking: low. Mark–recapture, parentage: high	High
Direction of dispersal identified?	No	Yes	Yes

13.7.4 Dispersal Ability

Dispersal doesn’t always result in gene flow, but it’s a necessary step. As expected, species that move more tend to have higher dispersal and gene flow. For instance, a study found that birds have an average maximum dispersal distance of 148.1 km, while mammals average 74.6 km, likely due to birds' ability to fly. Similarly, earlier in this Unit, we saw a correlation between dispersal ability and estimated gene flow (Nem), which supports the accuracy of these estimates, even though this argument is somewhat circular.

A more detailed way to assess gene flow is through isolation by distance (IBD). This concept suggests that gene flow between populations decreases as geographical distance increases since individuals are more likely to move to nearby locations. IBD is typically analysed by comparing gene flow estimates (often derived from FST values) with geographical distances using a Mantel test, which checks for correlations between genetic and geographic distances. This test is useful because it accounts for non-independent population comparisons.

A study on plant-feeding insects examined IBD patterns in 39 species. It found that moderately mobile species showed stronger IBD patterns than both sedentary and highly mobile species. This likely happens because sedentary species have high genetic differentiation even between nearby populations, while highly mobile species show little genetic differentiation even over long distances.

However, dispersal ability doesn't always predict gene flow accurately. For example, the soil-dwelling springtail, a small wingless insect, was expected to show genetic differentiation between populations, yet AFLP data revealed high gene flow even between populations that were 10 km apart. In contrast, a study on carabid beetles found that a fully winged species had similar population differentiation to a species with vestigial wings. These cases show that while dispersal ability is an important factor, it's not the only one influencing gene flow.

Figure 13.4 shows the data that examines the presence or absence of isolation by distance (IBD) in 39 species of plant-feeding insects with different dispersal abilities. IBD is identified when there is a significant correlation ($P \leq 0.05$) between gene flow and geographic distance. The results show that IBD is most common in species with moderate mobility. (Data from Peterson & Denno, 1998).

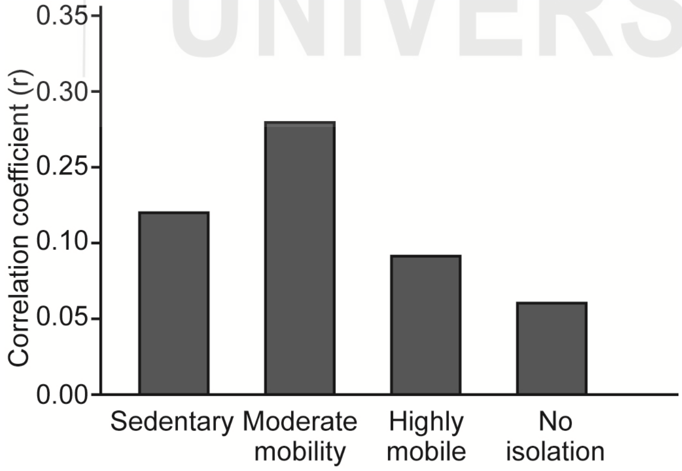

Fig. 13.4: Isolation by Distance in Phytophagous Insects.

13.8 MOLECULAR MARKERS AND PHYLOGEOGRAPHY

Phylogeography examines the distribution of genealogical lineages, with DNA sequences serving as the most reliable markers for inferring genealogies.

While microsatellites and AFLPs provide insights into genetic similarity *via* allele frequencies, they do not strictly align with Avise's original definition of phylogeography. Nevertheless, allele frequencies help assess gene flow and population subdivision, making them valuable in phylogeographic studies.

Mitochondrial DNA (mtDNA) has historically been the primary marker in animal phylogeography due to its ease of use, rapid mutation rate, and presumed clonal inheritance. Prior to 2000, nearly 70% of studies relied on mtDNA analysis. The availability of universal primers has further contributed to its widespread use. However, mtDNA's limitations include its representation of a single locus, susceptibility to selection, and potential for misleading results due to hybridisation or sex-biased dispersal.

To verify whether mtDNA accurately reflects population history, researchers compare it with data from nuclear or plastid genomes. In animals, nuclear markers provide additional insights but introduce complexities due to recombination. Since different parts of a nuclear locus can have distinct evolutionary histories, identifying and managing recombination is crucial. Software tools can detect recombination, and affected regions can be removed to improve analyses. This approach was successfully applied to the fungal pathogen *Sclerotinia sclerotiorum*, where multiple nuclear loci revealed population fragmentation patterns.

Most nuclear-based phylogeographic studies focus on specific genes, such as *bindin* in sea urchins. However, there is growing interest in single nucleotide polymorphisms (SNPs) due to their prevalence in the genome. While SNPs remain underutilised in non-model organisms, advancements in technology, such as a study on Scandinavian wolves, suggest increasing adoption in the near future.

Regardless of the molecular markers used, various analytical techniques play a crucial role in phylogeography. We will first explore traditional methods, such as molecular clocks and phylogenetic reconstructions, before delving into newer approaches tailored to phylogeographic data.

13.9 MOLECULAR APPROACHES TO BEHAVIORAL ECOLOGY

Behavioural ecology explores how an animal's responses to stimuli are shaped by its ecology and evolutionary history. This field covers diverse topics, including mate choice, brood parasitism, cooperative breeding, foraging, dispersal, territoriality, and offspring sex ratio manipulation.

Traditionally, behavioural studies relied on laboratory or fieldwork. Laboratory experiments allow controlled observations but may not fully replicate natural conditions, especially for species that cannot be kept in captivity. Field studies provide valuable insights but face challenges such as difficulty tracking individuals over time.

In recent years, molecular techniques have complemented traditional methods, particularly for studying wild populations. By analysing small biological samples (e.g., blood, hair, or feathers), researchers can determine genetic relationships, identify individuals, and gain deeper insights into behaviour.

This first examines how molecular data have enhanced our understanding of mating systems and kin selection. It then explores the use of sex-linked markers and, finally, how gene flow estimates and individual genotyping have contributed to studies of dispersal, foraging, and migration.

13.9.1 Mating Systems

In behavioural ecology, mating systems refer not to the biological modes of reproduction (sexual or asexual) but to the social structures surrounding reproduction, such as pair bonding. Over the past two decades, molecular studies have provided valuable insights into the fitness costs and benefits of various mating behaviours, often revealing unexpected patterns.

One key outcome of this research is the distinction between social mating systems, based on observed interactions between individuals, and genetic mating systems, which reflect actual parentage. Molecular genetic data have been instrumental in uncovering discrepancies between these two, deepening our understanding of reproductive strategies in different species.

13.9.2 Monogamy, Polygamy and Promiscuity

Animal mating systems generally fall into five categories (Table 13.5). Monogamy involves a pair bond between one male and one female, while polygamy—which includes polygyny, polyandry, and polygynandry—features multiple mating partners. Promiscuity refers to mating without lasting social bonds. However, many species exhibit more than one mating system, and the examples provided do not imply exclusivity to a single strategy.

Social monogamy is rare across most taxa, with the notable exception of birds, where approximately 90% of species engage in it. Behavioural ecologists have long explored why some species adopt social monogamy. The explanation is biparental care, where both parents contribute to offspring survival. This has been observed in species such as the California mouse (*Peromyscus californicus*) (Gubernick & Teferi, 2000), black-winged stilts (*Himantopus himantopus*) (Cuervo, 2003), and largemouth bass (*Micropterus salmoides*) (DeWoody et al., 2000).

Biparental care is more common in birds than mammals since both male and female birds can incubate eggs and feed nestlings. In contrast, mammalian parental care is often female-dominated due to gestation and lactation. This difference likely explains the higher prevalence of social monogamy in birds.

Table 13.5: Examples of Mating Systems across animal species.

Mating system	No. of males	No. of females	Examples
Monogamy	1	1	Prairie vole (*Microtus ochrogaster*), Hammerhead shark (*Sphyrna tiburo*), Polynesian megapodes (*Megapodius pritchardii*)
Polygyny	1	Multiple	Red-winged blackbirds (*Agelaius phoeniceus*), Fanged frog (*Limnonectes kuhlii*), Spotted-winged fruit bat (*Balionycteris maculata*)

Polyandry	Multiple	1	Galápagos hawk (*Buteo galapagoensis*), Gulf pipefish (*Syngnathus scovelli*)
Polygynandry	Multiple	Multiple	Variegated pupfish (*Cyprinodon variegatus*), Smith's longspur (*Calcarius pictus*), Water strider (*Aquarius remigis*), Jamaican fruit-eating bat (*Artibeus jamaicensis*)
Promiscuity	Multiple	Multiple	Soay sheep (*Ovis aries*), Long-tailed manakins (*Chiroxiphia linearis*)

If offspring can survive without paternal care and a male can attract multiple mates, polygyny may arise. This often occurs in species where resources, such as food, are distributed unevenly, allowing males to defend high-quality territories that attract multiple females. For example, in Gunnison's prairie dogs, monogamy is common when resources are evenly distributed, whereas polygyny or polygynandry occurs when resources are patchy and defended by one or more males.

In rare cases, the typical roles of males and females are reversed. In these species, females are often larger and more colourful than males that compete for and defend territories that attract multiple males, who then take on most of the parental care. This mating system, known as polyandry, is well-documented in the American jacana. Female jacanas defend large territories on ponds or lakes, where multiple males each maintain floating nests and incubate the eggs laid by the female. This system likely evolved due to habitat constraints, where suitable nesting sites are scarce and predation rates are high. By laying multiple clutches across different nests, female jacanas increase their reproductive success, while males, despite having limited choice in the matter, secure valuable nesting sites. Polygynandry occurs when multiple males and females form social bonds within a group. This differs from promiscuity, in which any female can mate with any male without forming social ties. Distinguishing between these two mating systems often requires detailed behavioural studies, and the terms are sometimes used interchangeably. Promiscuity is widespread, documented in at least 133 mammalian species, as well as in birds like sage grouse and fish such as guppies. Promiscuous mating can provide significant fitness benefits to both sexes. Males benefit by fertilising multiple females, while females may enhance offspring survival through genetic diversity, increased parental investment, and reduced risk of male infanticide. Field experiments on adders (*Vipera berus*) and crickets (*Gryllus bimaculatus*) have demonstrated that females who mate with multiple males produce offspring with higher survival rates, highlighting the evolutionary advantages of this strategy.

13.9.3 MATE CHOICE

Many studies using molecular data for parentage analysis have revealed a common pattern: even in socially monogamous species, both males and females often engage in extra-pair matings. However, not all individuals have equal success in attracting mates, raising the question of what traits make a mate particularly appealing. Mate choice can be exercised by both sexes. For instance, in blue-footed boobies, males with more vibrant feet experience higher levels of both intra- and extra-pair courtship, suggesting that foot colouration influences male attractiveness. Generally, females tend to be choosier than males because they invest more in egg production compared to the male’s investment in sperm. Understanding why individuals choose specific mates, both social and extra-pair, is key to understanding the evolution of mating systems.

Research on mate choice has grown rapidly, combining field observations, experimental studies, and molecular analyses. Two major hypotheses, supported by genetic data, help explain mate choice: the good genes hypothesis and the genetic compatibility hypothesis. While forced copulations, mate guarding, and intrasexual competition can limit mate choice, genetic parentage studies have provided valuable insights into why individuals select certain partners.

The **good genes hypothesis** proposes that individuals choose mates based on traits that consistently enhance offspring fitness. In Atlantic salmon, for example, individuals carrying the *MHC e* allele have higher survival rates in populations infected by *Aeromonas salmonicida* bacteria, making them valuable genetic contributors. This hypothesis also explains extra-pair fertilisations (EPFs) when a female mates with a genetically superior male rather than relying solely on her social partner. In great reed warblers (*Acrocephalus arundinaceus*), females engage in EPFs with neighbouring males that have larger song repertoires than their social mates. Since offspring survival is positively correlated with the genetic father’s song repertoire, females appear to select mates with beneficial genes.

The **genetic compatibility hypothesis** suggests that mate choice is influenced not by universally "good" genes but by how well a mate’s genotype complements the chooser’s own. This means that the same gene may enhance fitness in some genetic combinations but not in others. For example, female mice and sand lizards prefer mates with dissimilar *MHC* alleles, likely to increase offspring heterozygosity and reduce inbreeding. This hypothesis also provides a strong explanation for EPFs. In three shorebird species, females were more likely to seek EPFs when their social mates were genetically similar to them. Additionally, males in these species were more likely to fertilise quasi-parasitic females when their social partners were genetically similar, further supporting the idea that EPFs may function as a mechanism for inbreeding avoidance.

13.10 CONSERVATION GENETICS

Biodiversity encompasses all forms of life on Earth, including both species diversity and genetic variation. Preserving biodiversity is essential because ecosystems rely on a rich variety of species to function properly. Beyond maintaining life-supporting systems, biodiversity directly benefits humans by providing food (crops, livestock), fibres (wool, cotton), medicines (25% of prescriptions in the U.S. contain plant-derived ingredients), and recreational opportunities (hiking, ecotourism, zoos, gardening, fishing, and birdwatching).

However, biodiversity holds intrinsic value beyond its usefulness to humans. From an ethical standpoint, the dominance of *Homo sapiens* in driving species to extinction raises serious moral concerns. The fossil record indicates that biodiversity has generally increased over the past 600 million years, despite the fact that approximately 99% of all species that have ever lived are now extinct.

Most extinctions, around 96%, have occurred gradually, contributing to what is known as the background extinction rate. Fossil evidence suggests that, on average, 25% of all species go extinct every million years. The remaining 4% of extinctions took place during five mass extinction events, where at least 75% of species were lost in relatively short periods. The most recent and well-known mass extinction occurred at the end of the Cretaceous period (65 million years ago), wiping out approximately 85% of all species, including the dinosaurs.

Figure 13.5 shows that while the rates of species originations and extinctions have varied over time, originations have generally exceeded extinctions in most periods. (Data from Benton, 1993).

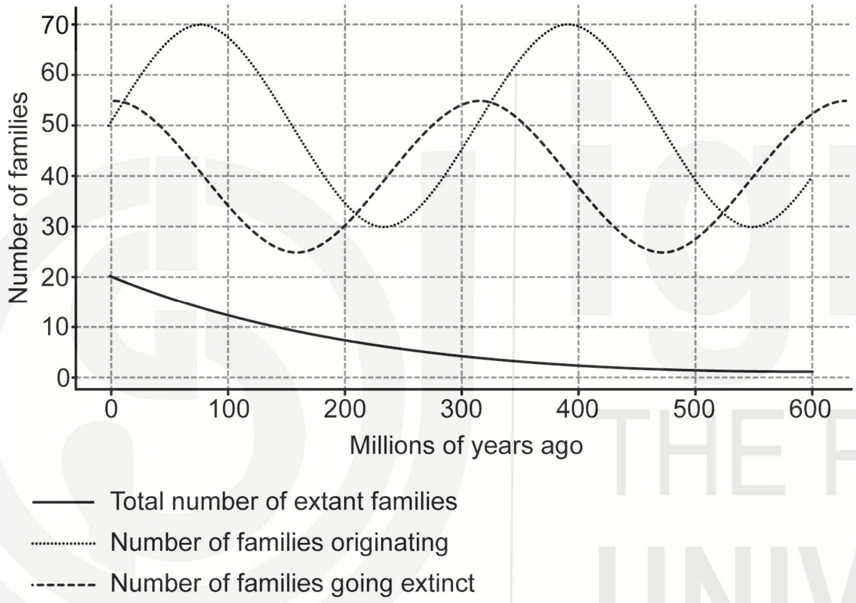

Fig. 13.5: Fossil evidence indicates that the total number of living families has steadily increased over the past 600 million years.

Many biologists believe we are entering a sixth mass extinction. Over the past 400 years, several hundred species have disappeared. While this may seem significant, these extinctions represent only a small fraction of described taxa and do not yet indicate a mass extinction event. The real concern lies in the predicted extinction rates for the coming century.

IUCN compiles Red Lists to assess species at risk, categorising them as critically endangered, endangered, or vulnerable based on factors such as population size, number of mature individuals, generation time, population trends, and habitat fragmentation. According to the 2003 IUCN Red List, 23% of mammal species and 12% of bird species were classified as threatened.

For many other taxonomic groups, our understanding remains incomplete due to limited data. For example, while 49% of evaluated fish species are classified as threatened, only about 5% of all fish species have been assessed. Similarly, 72% of evaluated insect species are considered threatened, but fewer than 0.1% of all insect species have been studied. Among plants, data are particularly scarce, except for conifers, where 93% of species have been evaluated, revealing that 31% are threatened.

Although these figures are incomplete, if similar proportions of species across all taxonomic groups are at risk, then a significant loss of biodiversity may be imminent (Table 13.6).

Table13.6: Threat Status of Taxonomic Groups: Described, Evaluated, and At-Risk Species.

Taxonomic Group	Number of Described Species	Number of Evaluated Species	Number of Threatened Species	Number of Threatened Species as % of Described	Number of Threatened Species as % of Evaluated
Vertebrates					
Mammals	4,842	4,789	1,123	23	24
Birds	9,932	9,932	1,211	12	12
Reptiles	8,134	401	16	4	4
Amphibians	5,578	401	3	39	39
Fishes	28,100	1,532	3	6	49
Invertebrates					
Insects	950,000	768	0.06	0.006	72
Molluscs	70,000	2,098	1	1	48
Crustaceans	40,000	461	1	1	89
Others	13,020	55	0.02	0.2	55
Plants					
Mosses	15,000	93	0.5	86	86
Ferns	13,025	180	1	8	62
Gymnosperms	980	907	31	31	34
Dicotyledons	199,350	7,734	3	7	75
Monocotyledons	59,300	792	1	2	65

This growing concern has led many to believe that we are on the verge of a sixth mass extinction. But what is driving so many species toward extinction? In most cases, the primary cause is human activity. Farming, logging, mining, dam construction, and urban development have devastated habitats worldwide. Many endemic species have been severely impacted by the intentional or accidental introduction of non-native species. Overexploitation through hunting, fishing, and wildlife trade has pushed numerous species to the brink, while industrial and agricultural pollution has further exacerbated the crisis.

Despite the varied nature of these threats, they often lead to a common outcome: declining population sizes. As populations shrink, they experience reduced genetic diversity and increased inbreeding, making them even more vulnerable to extinction. This is where conservation genetics plays a crucial role. In this Unit, we have explored how genetic data can help identify distinct species and populations in need of conservation. We have also revisited key genetic concepts such as genetic diversity, inbreeding, population sizes, and relatedness along with focusing on their applications in conservation biology.

SAQ 2

a) What is stabilising selection?

b) What is transient polymorphism?

c) What is an example of positive frequency-dependent selection?

d) What do RAPD and microsatellite data discussed in the Unit suggest about plant reproduction?

e) What does F = 0 and F = 1 indicate?

13.11 TERMINAL QUESTIONS

1. Write a brief note on Hardy-Weinberg equilibrium and its assumptions.
2. What is the difference between bottleneck and founder effect?
3. What re molecular markers?

13.12 ANSWERS

Self-Assessment Questions

1. a) Migration can mix individuals from different breeding populations, making it difficult to define a single population.

   b) Some species have dormant seeds or eggs that can remain inactive for years, leading to an underestimation of their true population size.

   c) The gene pool is the total genetic material within a breeding population.

   d) It is a principle stating that allele frequencies in a population remain stable if no evolutionary forces act on it.

   e) Mutation, natural selection, genetic drift, gene flow, and non-random mating can cause deviations from equilibrium.

   f) A population bottleneck occurs when a population size drastically decreases, reducing genetic diversity.

   g) It is a method that detects bottlenecks by analysing fluctuations in allele frequencies between generations.

2. a) It reduces genetic variation by favouring average phenotypes and eliminating extreme traits.

b) It is a temporary increase in genetic diversity before an allele reaches fixation.

c) In *Heliconius erato* butterflies, common colour patterns deter predators, favouring widely shared traits.

d) Outcrossing species generally have higher genetic diversity than selfing or mixed reproductive species.

e) F = 0 means no inbreeding, while F = 1 means complete homozygosity.

Terminal Questions

1. Refer to Subsection 13.5.1.
2. Refer to Subsection 13.5.2 and 13.5.3.
3. Refer to Section 13.8.

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